FOSSIL FUELS TO PRODUCTS

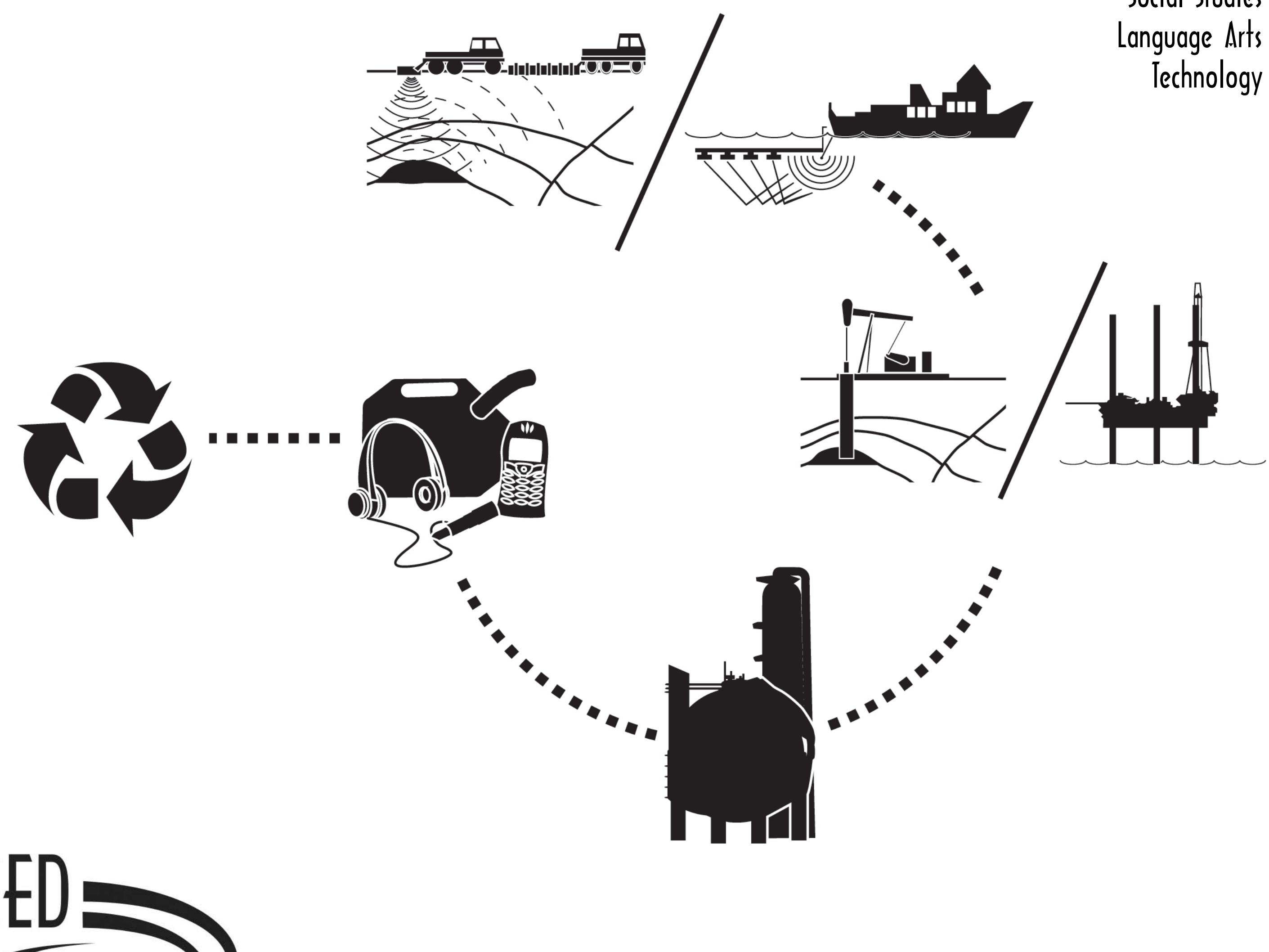
Students learn about exploration, production, refining, chemical manufacturing, transportation, marketing, and uses of petroleum, natural gas, and their products in the industrial sector, with background information and hands-on activities.

GRADE LEVEL

Intermediate/Secondary

SUBJECT AREAS

Science
Social Studies
Language Arts
Technology



NEED

2009-2010

Putting Energy into Education

NEED Project PO Box 10101 Manassas, VA 20108 1-800-875-5029 www.NEED.org

Teacher Advisory Board

Teacher Advisory Board Vision Statement

NEED Mission Statement

The mission of the NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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Fossil Fuels to Products *was developed by The NEED Project and the Center for the Advancement of Process Technology (CAPT).*

Funding for this project was provided to CAPT by Shell Oil Company and the National Science Foundation.

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Halliburton provided funding to NEED for distribution of the curriculum to teachers.

Special thanks to the Ohio Oil and Gas Energy Education Program for their assistance with teacher lessons for this guide. The OOGEEP provides teacher lessons and training to schools in Ohio. For more resources visit: www.oogeep.org

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Data is from the U.S. Department of Energy's Energy Information Administration.

Correlations to National Science Standards

(Bolded standards are emphasized in the unit.)

UNIFYING CONCEPT 1. SYSTEMS, ORDER, AND ORGANIZATION

a. **The goal of this standard is to think and analyze in terms of systems, which will help students keep track of mass, energy, objects, organisms, and events referred to in the content standards.**

b. Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of order—or regularities—in systems, and by extension, the universe; then they can develop understanding of basic laws, theories, and models that explain the world.

c. Prediction is the use of knowledge to identify and explain observations, or changes, in advance. The use of mathematics, especially probability, allows for greater or lesser certainty of prediction.

d. Order—the behavior of units of matter, objects, organisms, or events in the universe—can be described statistically.

e. Probability is the relative certainty (or uncertainty) that individuals can assign to selected events happening (or not happening) in a specified time or space.

f. Types and levels of organization provide useful ways of thinking about the world.

INTERMEDIATE STANDARD–E: SCIENCE AND TECHNOLOGY

2. Understandings about Science and Technology

a. **Scientific inquiry and technological design have similarities and differences. Scientists propose explanations about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations.**

c. **Technological solutions are temporary and have side effects. Technologies cost, carry risks, and have benefits.**

f. **Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world. Reducing risk often results in new technology.**

g. **Technological designs have constraints. Some constraints are unavoidable, such as properties of materials, or effects of weather and friction. Other constraints limit choices in design, such as environmental protection, human safety, and aesthetics.**

INTERMEDIATE STANDARD–F: SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

5. Science and Technology in Society

a. Science influences society through its knowledge and world view. The effect of science on society is neither entirely beneficial nor entirely detrimental.

b. Societal challenges often inspire questions for scientific research, and societal priorities often influence research priorities.

c. Technology influences society through its products and processes. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and to society. Social needs, attitudes, and values influence the direction of technological development.

d. Science and technology have contributed enormously to economic growth and productivity among societies and groups within societies.

e. Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students should appreciate what science and technology can reasonably contribute to society and what they cannot do. For example, new technologies often will decrease some risks and increase others.

Teacher Guide

TO TEACH STUDENTS ABOUT THE EXPLORATION, PRODUCTION, REFINING, AND CHEMICAL MANUFACTURING OF OIL AND GAS USING BACKGROUND INFORMATION, GRAPHIC ORGANIZERS, COOPERATIVE LEARNING AND HANDS-ON ACTIVITIES.

BACKGROUND

The United States uses more petroleum than any other energy resource. Petroleum products are used to manufacture many of the plastics and other vital products we use every day to maintain our lifestyle and economy.

TIME

Three to ten 45-minute class periods, depending on the number of activities you choose to conduct.

PREPARATION

1. Familiarize yourself with the information and activities in the booklet.
2. Make copies of the pages you are going to use for each student (two copies of the Survey for Pre & Post).
3. Make a transparency of page 28 if you are conducting that activity.
4. Gather the materials you need to conduct the hands-on activities, as listed in each activity. The activities are designed so that the materials are inexpensive; most materials are available in the school science lab, or can be obtained at hardware, pet, and craft stores. If you have difficulty locating any of the materials you need, please email NEED at info@need.org for information on where you can purchase the materials.

PROCEDURE

Activity One: Introducing the Unit

1. Introduce the activity by asking the students the following questions:

    What are petroleum and natural gas?
    Where do they come from?
    How are they retrieved?
    How are they turned into useful products?
    What petroleum products do we use every day?
    What is their impact on society in the U.S.?

2. Explain to the students that they will learn about all of these things by taking on the roles of experts in the industry and consumers in the jigsaw activity described below, as well as by participating in hands-on activities.
3. Have the students take the Survey to establish baseline knowledge. Have the students self-grade the surveys, determine the average number of correct answers as a benchmark, mark the surveys as PRE, and save them.

Activity Two: Jigsaw

1. Divide the students into six groups. Assign each group one of six specific roles, as listed below. These groups are the role groups. Also assign the students to presentation groups, in which they will share their role expertise. Each presentation group should include at least one member from each role group.

    - Geologist
    - ROVER Operator
    - Pipeline Inspector
    - Process Technician
    - Lab Technician
    - Consumer

2. Explain the jigsaw assignment to the students. Give each student the list of questions for his/her role group (page 24). Explain that the questions will guide their reading and research. Explain that they will be involved in answering the questions over several days as they participate in the readings and other activities. They will use the information they have gathered to design and present projects at the end of the unit in their presentation groups.
3. Instruct the students to use the background material, as well as outside research, to answer their questions as completely as possible.
4. When the students have read all of the background sections and completed their research, have the role groups meet to discuss their findings. Instruct the students to add to their notes any additional information provided by group members.
5. After the students have met in the role groups and completed their discussions, assign them to their presentation groups. Explain that these groups will synthesize the information collected by the different role groups.
6. Distribute copies of the presentation questions to each student. Instruct the presentation groups to work together to answer the presentation questions, collecting members' ideas from each of the role areas.
7. After the groups have answered all of the presentation questions, instruct each presentation group to choose a product with which to present their findings. Suggested products include a PowerPoint presentation, a brochure, an expo display board, a song or rap, a school newspaper article, an advertisement, a video, or any other format acceptable to the teacher.
8. Give the groups a timeframe in which to complete and present their projects.
9. Use the Presentation Rubric on the following page to evaluate the projects.

Organizers and Hands-on Activities

1. Divide the lessons into the four sections listed below. For each section, have the students read the backgrounder section listed and complete the graphic organizer for that section.
2. Complete the hands-on activities for each section and discuss the background information and activities before proceeding to the next section. Instructions for the hands-on activities and the materials needed are included with the activities. It is suggested that students record what they learn from the hands-on activities in science journals.

   Section 1: **Introduction** and **Exploration**

   Section 2: **Retrieving the Oil, Production,** and **Shipping Crude Oil**

   Section 3: **Refining** and **Shipping Petroleum**

   Section 4: **Chemical Manufacturing, Chemical Plant Equipment, Transportation, Health & Safety, Products**, and **Into the Future**
3. After the students have completed these activities, conduct the **Oil Industry in the Round** activity below to reinforce new vocabulary.
4. Return to Step 4 of the **Jigsaw** activity above and complete the activity.

Vocabulary Reinforcement Activity: Oil Industry in the Round

1. Make a copy of page 34 on cardstock and cut out the cards.
2. Distribute the cards randomly to the students. If you have fewer than 30 students in the class, give some students two cards. All of the cards must be distributed for the activity to succeed.

   If you have more than 30 students, have the remaining students serve as arbiters of disputes and allow them to participate in a second round.
3. Explain the instructions for the game, as follows:

   The student with the card labeled START reads the question that follows the word START, "Who has....."

   The student who has the answer stands up and responds by reading his/her card, "I have ——. Who has ——?"

   This procedure continues until every person has read his/her card and the question has returned to the Starter, who answers the last question, and says, "The End."
4. Collect the cards and redistribute randomly to play another round.

Synthesis Activity: Fossil Fuels to Products

1. Follow the instructions on page 35 for the **Fossil Fuels to Products** activity.

Evaluation

1. Evaluate individual student performance using the graphic organizers and science journals.
2. Evaluate presentations for the **Jigsaw** activity using the rubric below.
3. Have the students take the **Survey** again, self-grade, and determine the average number of correct answers to determine knowledge gain. Mark the surveys as POST and send to NEED.
4. Evaluate the entire unit with your students using the **Evaluation Form** on page 39 and fax to the NEED Project at 1-800-847-1820 or mail to:

NEED Project   8408 Kao Circle   Manassas, VA 20110

Survey Answer Key (The Survey is on page 36)

1. d   2. b   3. a   4. d   5. b   6. c   7. d   8. b   9. a   10. b   11. a   12. a   13. b   14. b   15. a   16. a

Production—Exploring Density

Densities: Oil: 0.881 g/cm^3 Copper: 8.93 g/cm^3 Aluminum: 2.70 g/cm^3 Nickel: 8.90 g/cm^3

Manufacturing—Safety Placard Answer Key

A: butane   B: calcium   C: benzene   D: sulfuric acid   E: phosphorus   F: methane

Web Resources

www.need.org/needpdf/OCT2005NewsletterWEB-1.pdf

http://capt.com.edu/virtualchemplant/

www.shell.com/us/energizeyourfuture/

Grading Rubric—Presentation Project

Grade	Content	Organization	Originality	Workload
4	Project covers the topic in-depth with many details and examples. Subject knowledge is	Content is very well organized and presented in	Project shows much original thought. Ideas are	The workload is divided and shared equally by all
3	Project includes essential information about the topic. Subject knowl-	Content is logically	Project shows some original thought. Work shows new ideas and	The workload is divided and shared fairly equally by all group members,
2	Project includes essential information about the topic, but there are 1-2 factual errors.	Content is logically organized with a few	Project provides essential information, but there is little evidence of original	The workload is divided, but one person in the group is viewed as not doing fair share of the
	Project includes minimal information or there are several factual	There is no clear organizational structure, just a compilation	Project provides some essential information,	The workload is not divided, or several members are not doing

Fossil Fuels to Products

Introduction to Oil and Gas

What is Petroleum?

Petroleum is a **fossil fuel**. Petroleum is often called crude oil, or just oil. It is considered a fossil fuel because it was formed from the remains of tiny sea plants and animals that died millions of years ago. When the plants and animals died, they sank to the bottom of the oceans. Over time, they were buried by thousands of feet of sand and sediment, which turned into sedimentary rock. As the layers increased, they pressed harder and harder on the decayed remains at the bottom. The heat and pressure eventually changed the remains into petroleum. Petroleum is classified as a **nonrenewable energy source** because it takes millions of years to form. We cannot make new petroleum reserves in a short period of time.

Even though oil and natural gas come from ancient plant and animal matter, in geologic time, they are young. Most oil comes from rocks that are about 400 million years old or younger. Scientists believe the earth is over four billion years old, with life existing on earth for about 3.7 billion years. Dinosaurs first roamed the earth about 248 million years ago.

Petroleum is an **organic compound** made of several carbon organic compounds such as hydrogen butanes and olefins, like all living things, and is an excellent source of energy. Because the living things that turned into petroleum did not have the opportunity to complete the decay process, there is a great deal of chemical energy in their molecular bonds.

Petroleum deposits are locked in porous rocks like water is trapped in a wet sponge. Petroleum, just out of the ground, is called crude oil. When crude oil comes out of the ground, it can be as thin as water or as thick as tar. The characteristics of the crude oil vary in different locations. Some crude is very clear and moves like water. This is usually called light crude. Other crude is very dark and almost a solid at normal temperatures.

History of Oil

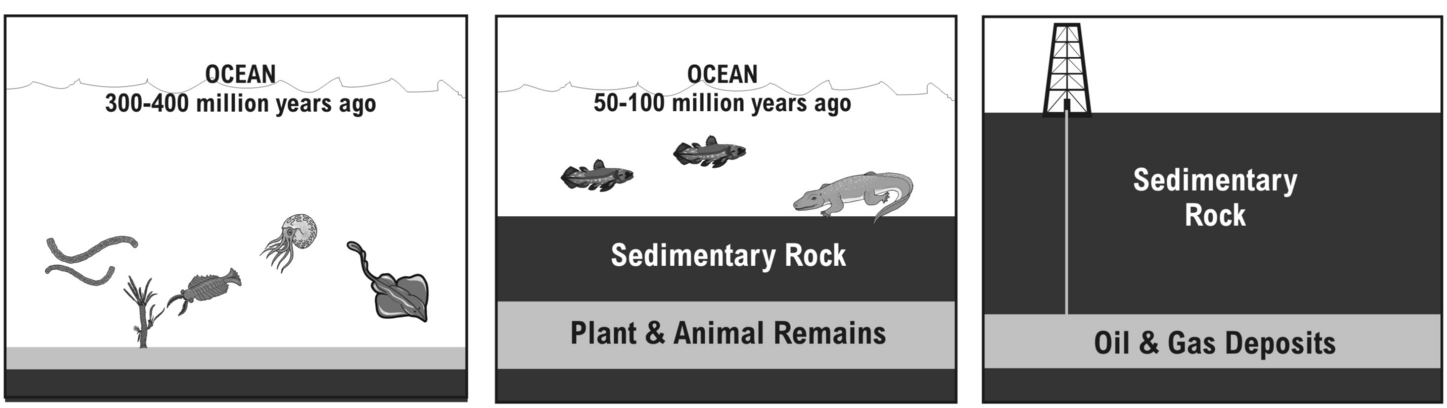
People have used petroleum since ancient times. The early Chinese and Egyptians burned oil to light their homes. Before the 1850s, Americans used whale oil to light their homes. When whales became scarce, people skimmed the crude oil that seeped to the surface of ponds and streams. Did you know that oil floats on water? The density of oil is less than the density of water, allowing it to float to the top.

The demand for oil grew and in 1859, Edwin Drake drilled the first oil well near Titusville, Pennsylvania. At first, the crude oil was refined into kerosene for lighting. Gasoline and other products produced during refining were thrown away because people had no use for them.

This all changed when Henry Ford began mass producing automobiles in 1913. Everyone wanted automobiles, and they all ran on gasoline. Gasoline was the fuel of choice because it provided the greatest amount of energy relative to cost and ease of use.

Today, Americans use more petroleum than any other energy source, mainly for transportation. Petroleum provides almost 39 percent of the total energy we use. Nearly one-third of the oil the U.S. produces comes from offshore wells. Some of these wells are a mile under the ocean. Some of the rigs used to drill these wells float on top of the water. It takes a lot of money and technology to find, explore, produce, and transport oil from under the ocean.

PETROLEUM & NATURAL GAS FORMATION

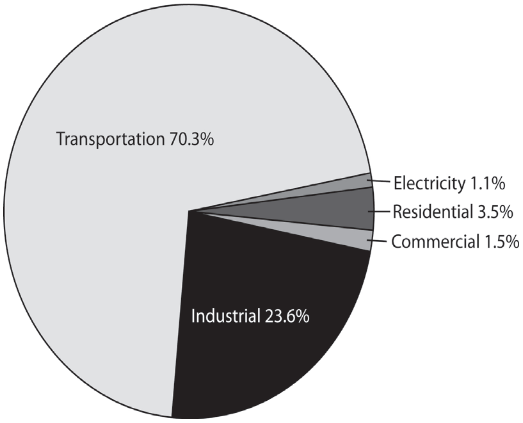


Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sedimentary rock.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.

2008 PETROLEUM USE BY SECTOR OF THE ECONOMY



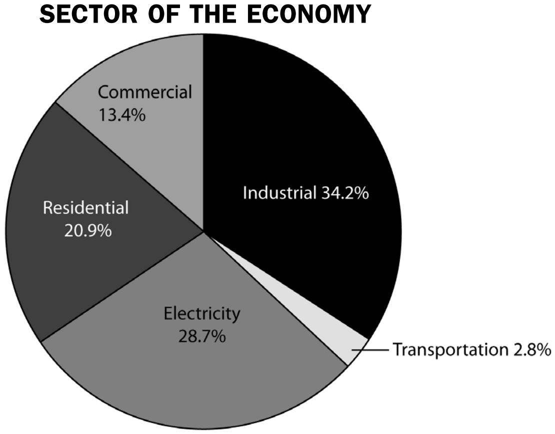
Texas produces more oil than any other state, followed by Alaska, California, Louisiana, and Oklahoma. Americans use much more oil than we produce. Today, the U.S. imports about two–thirds of the oil it consumes from foreign countries.

Oil and the Environment

Petroleum products—gasoline, medicines, fertilizers, and others—have helped people all over the world. Petroleum production and use are not without risk, however; environmental damage can result if oil and its products are not handled correctly. If drilling is not carefully regulated, it may disturb fragile land and ocean environments. Transporting oil may endanger wildlife if oil is spilled into rivers and oceans. Burning gasoline to fuel our cars pollutes the air. Even the careless disposal of motor oil drained from the family car can pollute streams and rivers.

The petroleum industry works hard to protect the environment. Gasoline and diesel fuel have been processed to burn cleaner, and oil companies do everything they can to drill, process and transport oil and its products as safely as possible.

2008 NATURAL GAS USE BY SECTOR OF THE ECONOMY



What Is Natural Gas?

Natural gas is a fossil fuel like petroleum and coal. Natural gas is considered a fossil fuel because most scientists believe that it was formed from the remains of ancient sea plants and animals. When the plants and tiny sea animals died, they sank to the bottom of the oceans where they were buried by sediment and sand, which turned into **sedimentary rock**. The layers of plant and animal matter and sedimentary rock continued to build until the pressure and heat from the earth turned the remains into petroleum and natural gas.

Natural gas is trapped in underground rocks much like a sponge traps water in pockets. Natural gas is really a mixture of gases. The main ingredient is **methane**. Methane has no color, odor, or taste. As a safety measure, gas companies add an odorant, **mercaptan**, to the natural gas that we use in our homes and buildings so that leaking gas can be detected (it smells like rotten eggs). Natural gas should not be confused with gasoline, which is a petroleum product.

Natural gas from underground reservoirs is considered a **nonrenewable energy source**, which means we cannot make more in a short time.

History of Natural Gas

The ancient people of Greece, Persia, and India discovered natural gas many centuries ago. The people were mystified by the burning springs created when natural gas seeped from cracks in the ground and was ignited by lightning. They sometimes built temples around these eternal flames and worshipped the fire.

About 2,500 years ago, the Chinese recognized that natural gas could be put to work. The Chinese piped the gas from shallow wells and burned it under large pans to evaporate seawater to make salt.

In 1816, natural gas captured from a coal coking plant was first used in America to fuel street lamps in Baltimore, Maryland. Soon after, in 1821, William Hart dug the United States' first successful natural gas well in Fredonia, New York. It was just 27 feet deep, quite shallow compared to today's wells. Today, natural gas is the country's second largest source of energy, meeting over 23 percent of our total energy demand.

Who Uses Natural Gas?

Just about everyone in the United States uses natural gas. Industry is the biggest user. Industry burns natural gas to produce heat to manufacture many of the products we use every day. Natural gas is also used as an ingredient, or **feedstock**, in fertilizer, glue, paint, laundry detergent, and many other products.

Residences, or homes, are the second biggest users of natural gas. Five in ten homes use natural gas for heating, and many also use it for cooking and heating water. Commercial buildings use natural gas, too. Commercial users include stores, offices, schools, churches, and hospitals.

Natural gas can also be used to generate electricity. Many utilities are building new power plants that burn natural gas because it is clean burning and natural gas plants can produce electricity quickly when it is needed for periods of peak demand. A small amount of natural gas is used as fuel for automobiles. Natural gas is cleaner burning than gasoline, but vehicles must have special equipment to use it. Many of the vehicles used by the government in national parks operate on compressed natural gas.

Natural Gas and the Environment

Burning any fossil fuel, including natural gas, releases emissions into the air, as well as carbon dioxide, a **greenhouse gas**. Natural gas (and propane) are the cleanest burning fossil fuels because they have fewer carbon atoms to form carbon dioxide. Compared to coal and petroleum, natural gas releases much less sulfur, carbon, and ash when it is burned. Because it is a clean source of energy, scientists are looking for new sources of natural gas and new ways to use it.

Exploration

Geology

Oil and gas are buried beneath the earth's crust, on land and under the oceans. To find it, **geologists** use their knowledge of land and rock formations, the geologic history of an area and sophisticated technology. Combining all this information, geologists are more likely to be successful when they drill. Even with all this, not all wells produce oil or natural gas. **Exploratory wells** are drilled if scientists think an area has oil. For every 100 exploratory wells drilled, about 44 of them will find oil.

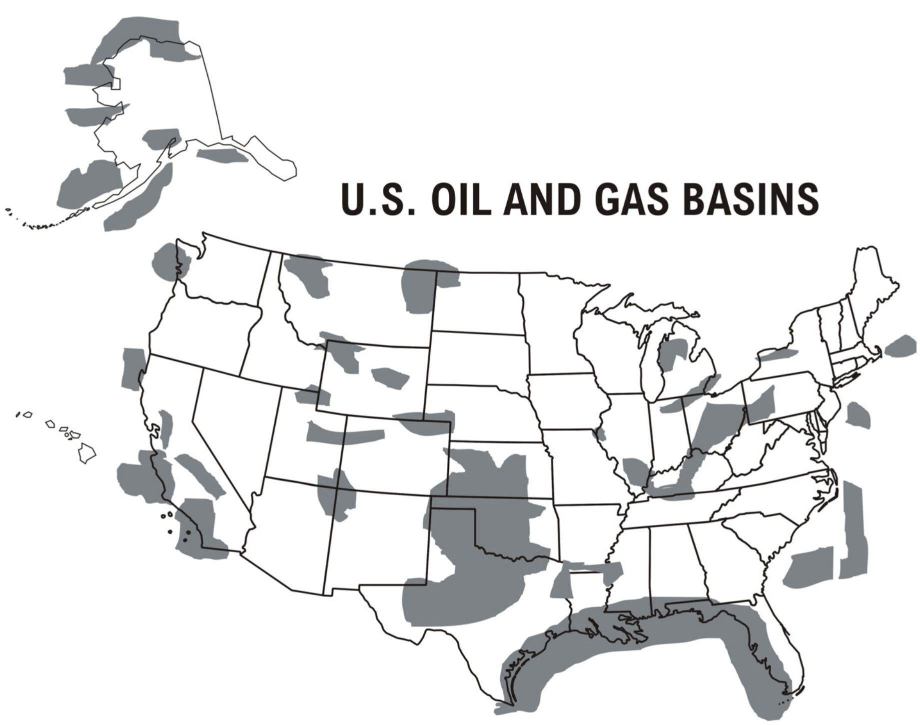
Forty-eight of every 100 exploratory wells drilled find natural gas. By the time production wells are drilled, the success rate has risen to about 85 percent. To increase the success of drilling, **petroleum geologists** must be knowledgeable in a number of areas.

Rock Formation

The field of **stratigraphy** is the study of rock layers (or strata) to determine the type of rock formation, the age of the layers, the radioactivity of the formations and other information to determine the composition, origin and location of rock strata.

Compiling information on rock formations is an important part of oil and gas exploration. Different types of rock have varying potential for holding oil or gas in a reservoir. There are three different types of rock: sedimentary, metamorphic and igneous; every rock fits into one of these three categories.

Metamorphic rock began as either sedimentary or igneous rock that was exposed to increased pressure and heat that eventually transformed it into metamorphic rock. Usually metamorphic rock is found near other types of rock. It is also usually denser than sedimentary rock since heat and pressure have removed many of the pores from it.



Igneous rock is formed from magma, or liquid rock, that exists in the earth's core. Sometimes where cracks or faults occur in the earth's crust, magma can seep up and cool, creating igneous rock. Igneous rock can also be created when magma makes its way to the earth's surface in the form of lava. Igneous rock is usually the densest of the three types.

Sedimentary rock is formed by the build-up of layers of sand and sediment over time. These layers are created as materials on the earth's surface are eroded and washed downstream. Over thousands of years, these particles are compressed to create rock. Most oil is found in sedimentary rock. Since sedimentary rock often has many pores, it is an ideal formation to contain oil.

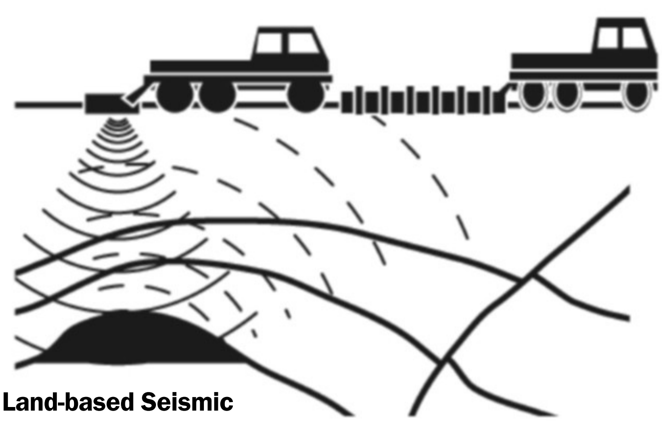
Permeability
Oil and natural gas occur naturally in the earth's layers, inside of rocks. Rocks are not completely solid; they have tiny holes, or pores, in which air or fluids were trapped during formation. ***The porosity of a rock formation is a measure of the number and kind of pores it has.***

Fluids can move between rock pores in varying degrees. ***Permeability is a measure of the ability of a rock to move fluids through its pores.*** Permeability is a very important feature for finding oil and gas. Being successful at finding oil is partially determined by locating porous rock, as well as locating other fluids, such as water, that are contained in rock formations.

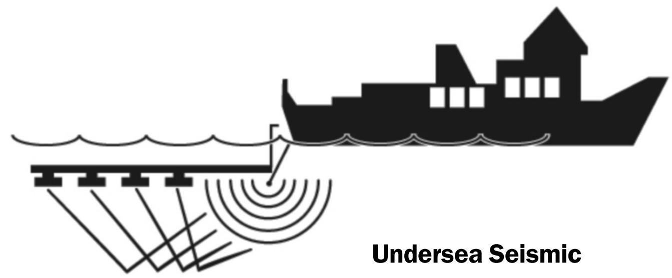
Geologic History
An important factor in finding oil and gas is understanding the environment that existed in an area millions of years ago. Since oil and natural gas are the remains of ancient sea life, the first step in locating oil is finding areas where ancient seas once existed.

Seismic Technology
Seismic technology uses sound waves to reveal what lies deep in the ground. Sound waves can travel through some materials more easily than others. When sound waves are directed into the ground and they hit something they cannot penetrate, they bounce back, returning to the surface. Equipment on the surface records the returning waves. Once the waves have all been recorded for an area, the information is taken back to a lab where **geoscientists** read the waves. A map can then be created of the underground terrain.

The first seismic instruments were used in the mid 1800s to detect earthquakes. Seismic equipment began being used in the oil field in the 1920s. In those days, dynamite was used to create the sound waves. The data collected had to be read by hand. In the 1960s, digital technology allowed the information to be read by machine. Three-dimensional seismic data was first used in the late 1960s and changed the way seismographs were used. Today, machines called **thumpers** are used to create shock waves instead of dynamite. To create a 3D image of the layer of ground, not one, but many seismic instruments are used. They are placed in holes around a site. Each of these instruments records sound waves. Then scientists can combine all of these images to get a better understanding of what lies underground.


Land-based Seismic

When searching for oil under the sea floor, seismic equipment must be adapted for the marine environment. Seismic systems are placed on ships and the listening devices are attached to long streamers. Many ships have four or five streamers, but some larger ships may have up to 16 streamers.


Undersea Seismic

Another way scientists analyze the ocean floor is with ocean bottom cables. These cables are sent to the ocean floor from a stationary platform. Then, a ship towing air guns passes by. The air guns, directed down, are used to create the sound waves.

Interpreting Seismic Output
Today, seismic data is interpreted in high tech ways. 3D visualization puts seismic information into a three-dimensional format that people can more easily understand. One of the most advanced 3D visualization projects is known as a **CAVE (Cave Automatic Virtual Environment)**. The CAVE is an entire room used for visualization. In this virtual reality environment, the walls and floor are used as projection surfaces giving the appearance of filling the room, allowing scientists to walk into the data.

The newest type of seismic technology is 4D seismic. The fourth dimension is time. 4D seismic uses a number of 3D images taken over time to see how they change. This technology is often used in areas that are already producing oil to see how production is affecting the reserve.

Other surveying techniques include gravitational, magnetic and radioactive processes, all of which measure physical properties of a site and use that information to determine whether oil or gas is present.

Retrieving the Oil

Permitting and Leasing Land

Once a site has the potential for oil extraction, companies must get permission to drill. In some areas, this means acquiring the needed permits from state government and leases from landowners to drill on private land. In other cases, the land is federal land and require leases and permits from the U.S. Bureau of Land Management or Minerals Management Service. There are also environmental protection measures that must be in place before drilling can begin.

Drilling

Since the first oil well was drilled in 1859 by Sir Edwin Drake, oil production has become an increasingly complex and precise process. The original methods of drilling for oil were based on ancient methods for finding water and salt. As wells have gotten deeper and more complex, drilling technology has also become more complex.

To drill a well, a large **drilling rig** is brought to the site. Once it is situated above the desired location, drilling can begin. **Roustabouts** work on the rig and handle many of the different elements of drilling.

Drill Pipe

Drill Bits

Drill bits have sharp teeth that rotate to tear apart rock while the well is drilled. As the well gets deeper, lengths of 30-foot pipe are attached to the top of the drill. Each 30-foot section must be lifted above the last section into the sky and screwed onto the previous section. This is one of the reasons drilling platforms are very tall.

When drilling an oil well, the rock that is torn by the drill bit (called **debris**) does not come easily to the earth's surface. As the hole gets deeper, debris can get in the way, blocking the hole. For this reason, drillers use mud to lift debris out of the well. **Drilling mud** originally was actual mud found on the drill site. Today, mud is a complex material specifically made for its purpose. Because it is so complex, mud is one of the biggest expenses in drilling.

Mud flow is controlled by the mud engineer. It is pumped down the hollow drilling pipe. It comes out near the drill bit, cooling the bit. The mud then carries debris up through the well as it is pumped, to be collected above ground. One of the reasons mud is so expensive is that it must be formulated with precise **density**. Since less dense materials float on top of more dense materials, the mud must have a greater density than the rock that is being cut. Drilling mud also keeps the formation, or walls of the well, from collapsing inward.

Once a well has been drilled to the depth of the oil reservoir, the workers move into the next stages—well completion and production. The drilling rig is removed from the site and the well is prepared to begin producing oil.

Well Completion

After a well is drilled, it must be completed before it can begin producing. There are three main steps in the **completion process**. The first is allowing oil into the well so that it can be brought to the surface. The second is making sure that water does not get into the well, and the third is keeping underground rock out of the well.

Completion is not done the same way for all wells. Deciding what to do depends on a number of factors, including the size and shape of the oil reservoir, the surroundings of the reservoir, and the kinds of rocks and oil the reservoir contains.

Oil is contained within rock formations. The nature of these formations affects the way oil is pumped from the ground. There are two characteristics that are very important to predicting how the oil will flow. The first characteristic is porosity. **Porosity** pertains to the gaps, or pores, between the grains in the rock where oil is stored. **Permeability** is the second important characteristic; it measures how many of those pores connect to each other. Knowing if the pores connect is important, since these connections are what allow oil to flow to the well. Even though a rock formation is very porous, if it has no permeability, the oil will be difficult to extract.

Most oil formations also contain water, or **saturation**, near or mixed in with the oil. Producers must be sure to separate this water out of the formation. They must also be sure to avoid contaminating nearby ground water, land, and underground aquifers.

The amount of **pressure** in a formation is another factor that is very important. Since oil extraction removes mass from the earth, the stability of the reserve is something that must be considered. While some formations can maintain their shape when oil is removed, others cannot. These formations must be stabilized, allowing them to remain open for fluids to flow.

The last issue to be considered is how well the reserves are connected. **Compartmentalization** is a situation in which the oil from one part of the reserve cannot flow to another part of the reserve. There may be faults in the ground that disconnect the layers, or pores from one section may not be connected to other sections because of low permeability. There can also be streaks of other types of rock that the oil cannot easily pass through between the well and the oil, or there may be other barriers in the way of the flow.

Once all these issues are taken into consideration, completing the well may begin. To start completion, the well must be open so that oil can flow into it.

Casing the Well

Drill pipe does not stay in the well after it is drilled. It is replaced with longer, wider **casing pipe**, which is used to line the well. Usually, casing a well begins before the end of the drilling process. Casing the top of the well occurs as the drill continues to dig deeper into the ground. The final and deepest casing is placed in the well after drilling is complete.

The rock around the well is crushed to allow the oil to flow freely. Shooting nitroglycerin and shattering the rock in the immediate area can crush the rock. The sides of the well, or the casing, blocks oil from getting into the well itself. At the levels where oil is present, the casing is perforated to let oil flow. **Perforating** the casing is done by shooting a very thin fast jet of gas to penetrate and perforate the casing.

Cementing

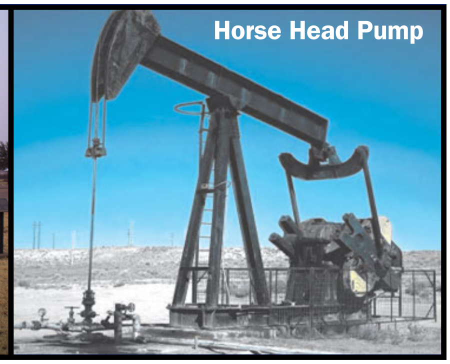
Once casings are in place, cement is used to fill in the gap between the casing pipes and the well wall. Drilling mud is pumped out of the well as cement is pumped in. As the cement is pumped in, the casing is slowly rotated to create a better bond with the cement.

Production

Once the wells have been completed, they can go into production. Production wells do not have the complex aboveground structures that are in place during drilling. Instead, the wells are capped with smaller units. Ideally, oil is extracted using **natural drive**, which means there is enough pressure in the well to move the oil and no pumping is needed. Wells with natural drive have christmas trees above ground. A **christmas tree**, in the petroleum industry, is a series of valves and gauges used to measure and control the flow and pressure of the well.

Other wells do not have enough natural drive to move oil out of the earth. They must use pumps to lift the oil to the surface. Typically, this is done with a **sucker-rod pump**, sometimes called a **horse head pump** because of its shape. Using one-way valves underground near the oil formation, the pump draws, or sucks, oil to the surface. As the horse head pump above ground goes up and down, valves below lift the oil. Pumps may run for only a few hours each day to avoid distorting the way the fluids are distributed underground. Many wells produce only a few barrels of oil a day.


Christmas Tree


Horse Head Pump

In a well that has a lot of pressure, a **blow out preventor,** or **BOP**, is used to avoid explosions. A BOP includes monitors to ensure the well is operating correctly and a set of controls that react to any unexpected pressure change. If there is too much pressure, the man-made elements of the well could be forced out the top of the well or fire could occur.

To monitor a well's progress, comprehensive **data logs** are kept that track a number of different factors. Radioactive, electric, mechanical and sonic tools are just some of the ways wells are studied. If monitors indicate unusual well behavior, engineers investigate and attend to the problem.

Subsea Operations

In offshore operations, well completion and production are similar to onshore, but they take place below hundreds or thousands of feet of water. Well caps must be resistant to corrosion by salt water and must be able to withstand the pressure deep in the ocean. Well operators do not regularly visit the ocean floor to check on the well caps. Instead, sensors are placed on the well caps so that the wells can be monitored from the platform. Advanced technologies such as **Remote Operating Vehicles**, or **ROVERS**, can make robotic repairs to the well by operators on the platform using remote controls.


Offshore Drilling Rig

The oil is piped to an offshore **processing platform** where it is combined with oil from other wells before being cleaned and sent to a refinery. There is a limited amount of space on an offshore platform to store new oil, so all of the operations must be carefully coordinated. Production supervisors oversee the entire operation of an offshore rig to make sure operations are moving smoothly.

Cleaning the Oil

Once oil has been brought to the surface, it must be cleaned. Refineries have specific standards that they require suppliers to meet before they will accept the oil. Producers usually clean their oil on site, near the pump. If a producer has multiple wells near each other, there may be one processing facility for a number of wells.

Field processing is used to separate out oil, gas and salt water. All of these materials can come up through the well mixed together. The simplest way to separate out the different materials is in **settling tanks**. Oil from the ground is pumped into a tank through one pipe and allowed to settle. Each layer of oil, gas, and saltwater is then pumped out through its own pipe. The downfall of this method is that settling can take a long time.

Pressurized separators that have a higher capacity and separate more quickly can also be used. Inside these separators, pressure is used to collect liquids at the bottom, while oil and gas are piped out the side. Separators do a good job of separating oil and gas, but more processing is needed to remove all of the saltwater.

When oil and water are mixed together, they can be difficult to separate. This is true for household vegetable oil and tap water and it is true for crude oil and salt water. Refineries require that the oil contain no more than one percent water.


Oil Pipeline


Offshore Production Platform

To remove excess water, heat is applied with a **heat-treater**. The heat-treater causes the droplets of water that are suspended in the oil to come together, creating larger drops that can be more easily removed from the oil. Water-free oil is removed from the top.

Shipping Crude Oil

Oil wells are located above oil-bearing formations, wherever they are found. Refineries are usually near oil consumption markets, though many are located near major oil producing areas, as well. There are different ways to get the oil from well to refinery.


Oil Tanker

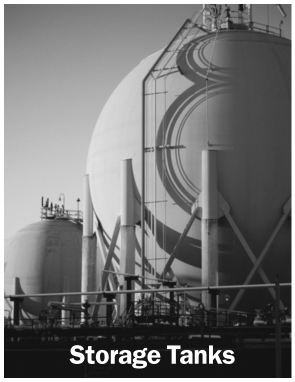
Much of the oil we use is shipped via pipeline. **Oil pipelines** move crude oil from oil platforms offshore in the Gulf of Mexico to refineries onshore. Pipelines can also move petroleum products between regions of the U.S. **Pumping stations** along the pipelines are located every 60 to 100 miles to keep the oil flowing.

A pipeline must be kept clean. To clean the inside of a pipeline, an instrument called a **pig** is used. This instrument is shaped like a bullet and scrubs the wall of the pipeline. More advanced pigs, called **smart pigs**, use cameras to monitor the pipe for flaws.

For longer distances, oil is put in tanker trucks or moved by sea on oil tankers. Crude oil produced in Venezuela, for example, is carried to the U.S. in oil tankers. This oil is offloaded at a refinery to be turned into useful products. Oil tankers have two hulls, or shells, to help prevent oil spills.

In most cases when oil is shipped by tanker, the crude oil travels though both pipeline and tanker. One example is crude oil produced on the Northern Slope of Alaska. This oil field is very far north, near the Arctic Ocean. Instead of building a port to bring tanker ships into these treacherous waters, a pipeline was built to carry the oil to a more easily reached port in the southern part of Alaska.

After transportation by oil tanker or pipeline to a refinery, much of the crude oil is placed in storage facilities or **tank farms**. These large cylinders hold the crude oil until the refinery is ready to process it.


Storage Tanks

Refining

Distillation

In its crude form, petroleum is of little use to us. To make it into products we know and use, petroleum must be **refined**—separated into its many parts. Those parts are what we use to fuel our world. Petroleum is made of hydrocarbons. ***Hydrocarbons are chemical compounds containing only hydrogen and carbon.*** These two elements combine in different ways to make hundreds of different compounds that we use to make thousands of products.

To separate petroleum products, oil is refined. The first and most important step in the refining process is distillation. Distillation has been around since ancient times. Stills were set up by many cultures to produce alcohol. The first distillation of oil was done at the world's first oil refinery in Romania in 1856.

Distillation is the separation of substances based on their boiling range. Petroleum is not the only thing that is distilled. The chemical industry and the beverage industry also distill their products. Basic distillation follows the same steps regardless of what is being separated.

A mixture is heated. As parts of the mixture begin to boil, they rise as gases. These gases are captured in a **fractioning tower**. While the bottom of the tower is very hot, the temperature at the top of the tower is cooler. Trays are placed at different levels inside the tower. These trays have holes in them so that gases can pass through. But as the gas meets a plate that is cooler than the temperature of that gas, it **condenses**, or turns back into a liquid. The condensed liquid that forms on each plate is sent to a pipe. Each plate has its own pipe that carries only the liquids collected on it. The separated liquids move to other machines for further processing.

There are a number of products that come from the refining process. Hydrocarbons with simple molecular structures have lower boiling temperatures. As the molecular structures become more complex, the boiling temperature increases—more energy is required to break the intra-molecular forces between the molecules, which allows for the phase changes.

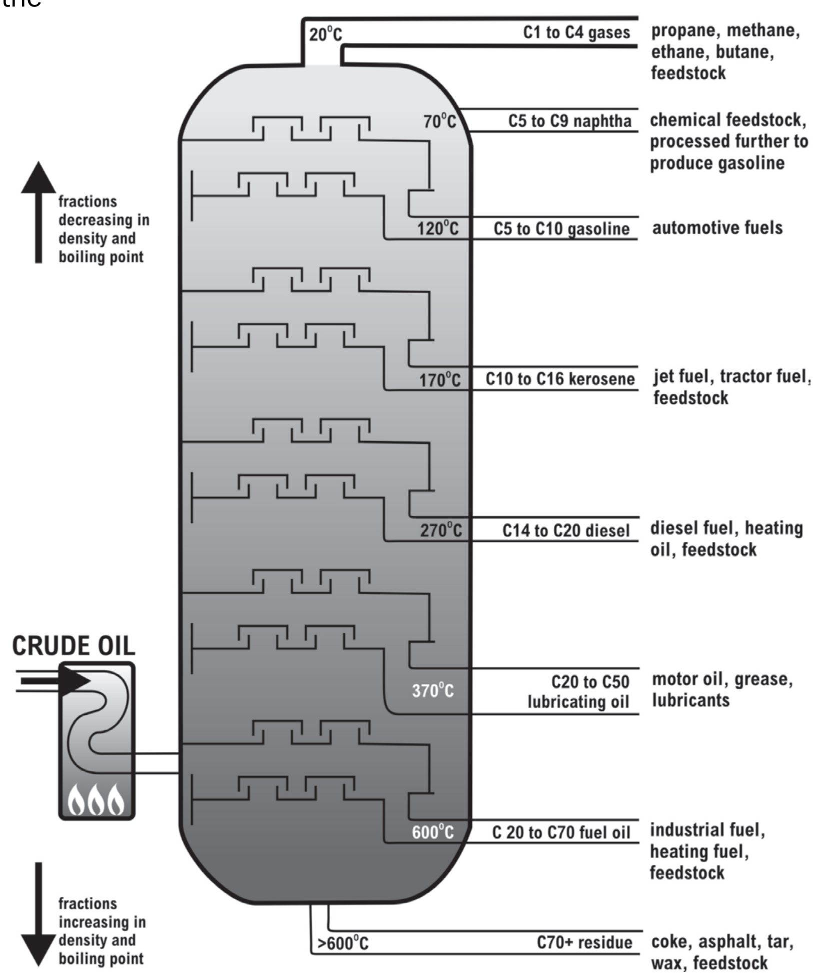
Once distillation is complete, the light, higher value products are cleaned and put to use. Heavy, lower value products are subjected to additional processes to either extract higher value products or alter their chemical make-up to produce higher value products.

Processing

These different parts are sent through chemical processing to be turned into useful products. There are three main types of processes. The first is called **cracking**, which breaks long hydrocarbon chains into smaller ones. **Unification** combines small chains into longer ones. **Alteration** rearranges pieces of hydrocarbon chains to make different hydrocarbons.

Cracking can be done in a number of different ways. One method is thermal cracking. **Thermal cracking** uses very high temperatures to break apart long chains of hydrocarbons. This can be done using high temperature steam.

Fractioning Tower



Cracking can also be done by heating the residue from distillation towers to very high temperatures until it separates into useful parts. This process is also known as **coking**, since the material that is left after all of the useful hydrocarbons are removed is **coke**, a hard, porous carbon material. Coke is used by heavy industry, such as iron and aluminum manufacturing.

Another way that long hydrocarbon chains are broken is through **catalytic cracking**. A catalyst is a material that increases the rate of reaction. Catalytic cracking is used to change heavy diesel oils into diesel oil and gasoline.

When smaller hydrocarbons are combined to make larger ones through **unification**, they usually undergo a process of **catalytic reformatting**, a process that converts naphtha into aromatics. **Aromatics** are **cyclic hydrocarbons**—meaning the carbons form a ring rather than the simpler straight chain hydrocarbons. Aromatics are typically used to make chemicals and blend gasoline. The main byproduct of catalytic reforming is hydrogen gas.

Alteration is the rearrangement of molecules in a hydrocarbon to create a more useful hydrocarbon. Usually this is done with **alkylation**, a process in which hydrocarbons are mixed with a catalyst and an acid to create hydrocarbons that are high in octane. These high-octane hydrocarbons are blended into gasoline.

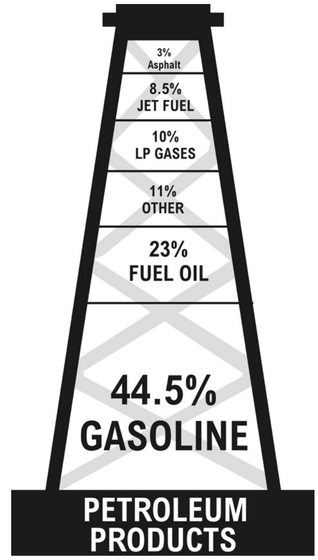
Preparation to Market

Once all the products have been separated from the crude oil that went into the refinery, the products must be prepared to go to market. This last step is known as **treatment**. Gasoline, for example, is treated with additives that help engines operate more smoothly and burn cleaner.

From the refinery, different petroleum products make their way to a variety of places. Almost half of every barrel of oil is made into gasoline. Another 10–15 percent is refined into other transportation products such as jet fuel, diesel fuel and motor oil. Many of these products are produced by further chemical processing.

Shipping Petroleum

After the refinery, most petroleum products are shipped to markets through pipelines. Pipelines are the safest and most cost effective way to move big shipments of petroleum. Gasoline is transported around the country through pipelines, most of which are buried underground. There are about 230,000 miles of underground pipelines in the U.S. It takes about 15 days to move a shipment of gasoline from Houston, Texas to New York City.



Special companies called **jobbers** buy petroleum products from oil companies and sell them to gasoline stations and to other big users such as manufacturers, power companies, and large farmers.

Chemical Manufacturing

Petroleum goes into much more than just the tanks of our cars and airplanes. Petroleum is part of many of the products we use every day. It is well known that plastics are made from petroleum products, but that is only the beginning. Your toothbrush, toothpaste, shampoo, and even your contact lenses contain petroleum, as do carpeting, CDs, the ink in your pen and medical devices such as prosthetic heart valves.

Chemical plants take refinery products and turn them into the products we use. There are many different kinds of chemical plants. Some are small and produce one or two items. Some are very large and produce a number of items. The largest plants can produce over 5 billion pounds of product each year. Large chemical plants operate all the time. They run twenty-four hours a day, every day of the year. Many of these plants are automated with new technology and need fewer people than in the past to run them.

Plant Equipment and Processes

Cracking in a chemical plant is very similar to cracking in a refinery. Heat is used to break apart the chemical bonds of the hydrocarbon molecules in feedstocks. ***Feedstocks are the raw materials used to make products in chemical manufacturing plants.***

Furnace

Boilers & Furnaces
Both boilers and furnaces are important parts of chemical plants. Often feedstocks are brought to a chemical plant in solid form, such as powder or pellet. To work with these materials, they must be heated and melted into liquids or sometimes gases.

Cooling Towers
Cooling towers are used to return the water used in chemical processing back to normal temperature before it is returned to the river or lake from which it was taken. To do this, water is sent through a maze-like structure that allows as much air as possible to come into contact with the water. Gravity pulls the water down through this maze, cooling it as it goes.

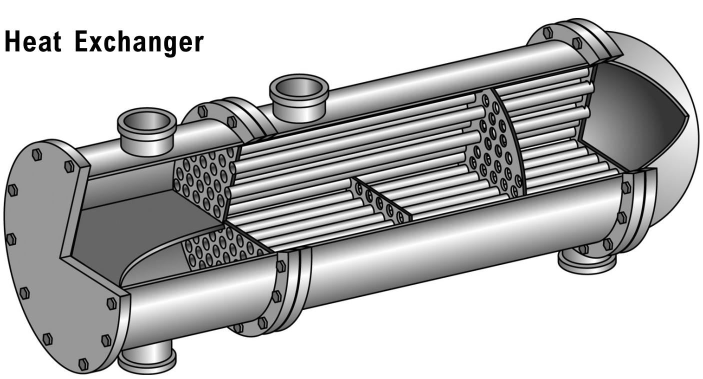
The air inside a cooling tower heats up as it comes into contact with the warm water being fed into the tower. The warming air rises, collecting a tiny bit of water vapor in the process, and is released from the top of the tower. As you drive by a chemical plant, you can sometimes see a cloud of water vapor rising from the cooling tower.

Heat Exchangers
Heat exchangers are devices that can speed up production and cut down on the need to process waste heat at the same time. Heat exchangers use fluids that contain waste heat, or heat that is no longer useful from a previous step, to heat materials that must be warmed in another step.

Heat exchangers are large pipes with smaller pipes inside. The small pipes carry cool liquids that need to be heated. The small pipes do not completely fill the large pipes, and the space around the small pipes is where the waste-heat fluid (liquid or gas) flows.

As the cool liquid and the hot fluid flow past each other, heat is transferred from the hot fluid to the cool liquid. At the end of the heat exchanger, the cool liquid has warmed in preparation for its next step. The hot fluid has cooled and requires less processing.

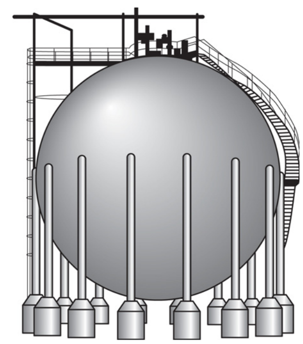
Heat Exchanger



Wastewater Treatment
Processing chemicals can use large quantities of water. Water is present in nearly every step. Boilers, cooling towers and heat exchangers all use water. To ensure that the water leaving the plant is as clean as the water coming into the plant, wastewater treatment facilities are located on site.

Laboratory
One important part of a chemical plant is the laboratory. Chemists constantly monitor the product at each step to make sure it meets the required specifications. If the chemistry is not just right, plastic bags could be too weak to hold groceries or nylon thread too brittle to sew. Chemists also monitor waste products to make sure the land and water is not being polluted.

Loading Station
Once the final product is complete, it is stored in a warehouse or storage tank, depending on the type of product. When needed, the product is taken from the storage facility to a loading station to be transported to market or to another chemical plant for further processing. Depending on the product, it may be transported by road, rail, air, water or pipeline.



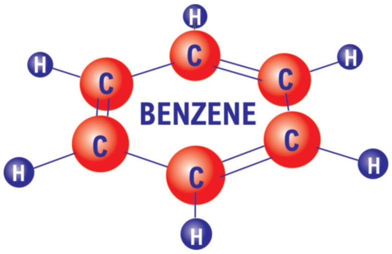
Sphere Storage Tank

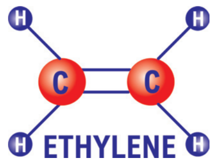
Transportation
Refineries and chemical plants are located all over the country and feedstock is often moved long distances between the two. Sometimes, chemicals are moved in small 50-pound bags or 400-pound drums. Feedstocks that must be transported in large quantities may be moved by barge, ship, or pipelines, which can carry larger quantities of product.

Products
To get the products that are familiar to us, feedstocks must be processed. Different products have different steps that are needed. Many products are made from more than one feedstock, which are combined in different ways to produce a variety of products.

There are two general types of chemicals produced from petroleum that are used to create most everyday items—aromatics and olefins. **Aromatics** are a group of petrochemicals with a distinctive sweet smell that are characterized by ring structures, and are produced in refineries and petrochemical plants. The most common aromatics are **benzene**, **toluene** and **xylenes**.

Aromatics are used for chemical production or as high-octane components for gasoline blending. Aromatics are used to make plastics and polymers. These go into products such as paint, textiles, building materials and leather alternatives.





Olefins are a class of hydrocarbons recovered from petroleum that contain one or more pairs of carbon atoms linked by a double bond. Typical examples include **ethylene** and **propylene**. Olefins are obtained by cracking petroleum fractions at high temperatures. Another word for olefin is alkene.

The simplest olefins—ethylene, propylene, butylene, butadiene, and isoprene—are the basis of the petrochemicals industry. They are used to produce plastics, industrial solvents, and chemicals that are used in other applications. A number of familiar products come from these petrochemicals, including plastic bags, paint, tires, and plastic bottles.

Health and Safety

Worker health and safety are top priorities in all process industry facilities. To help ensure that workers are safe on the job, all manufacturing plants follow OSHA (Occupational Safety and Health Administration) rules and guidelines.

In many work settings, for example, OSHA guidelines require that workers wear hardhats, ear protection, eye protection, or other safety gear.

Chemical plants are continuously making their operations as safe as possible. Spill kits are located throughout a plant so that if there is a spill, clean up can be accomplished quickly. Plants also work hard to replace any materials used in their processes that are toxic with alternatives that are safer for workers and for the environment.

One safety feature at a chemical plant is the **fire pond**. A pond of water is kept on site ready to be pumped if a fire were to erupt. There are usually a number of ponds scattered around each plant site so that one is never far away if it is needed. Since fire pond water does not need to be as clean as the water we use in our everyday lives, storm water is often collected to fill the ponds.

Into the Future

As the demand for petroleum products grows and the issues become more and more complex, energy companies are using advanced technologies to design and deliver next generation fuels and products. The skills used by all workers in the petroleum product industry are transferable to these new technologies; new opportunities are emerging every day.

Consumers can make a real difference by recycling petroleum–based products and buying products that conserve energy.

To take a tour of a chemical plant, go to the Center for the Advancement of Process Technology's Virtual Chemical Plant at http://capt.com.edu/virtualchemplant/.

Careers in the Oil and Gas Industry

The Oil and Gas Industry offers a variety of careers for individuals to work at its refineries, chemical plants, or on exploration and production onshore/offshore facilities. The following are an example of some of the career options available:

Process Technicians - member of a team of people that control, monitor, and troubleshoot equipment and focus on safety and environmental considerations

Instrumentation Technicians - maintain, calibrate, adjust and install measuring and control instruments necessary to ensure the safe efficient operation of equipment

Electricians - read blueprints that show the flow of electricity, maintain and repair the electrical and electronic equipment and systems that keep the facilities up and running

Machinists - install, maintain, repair and test rotating mechanical equipment and systems

Geologists - explore the nature and structure of rock layers to piece together a whole picture of the subsurface in order to determine the best possible places to drill for oil and natural gas

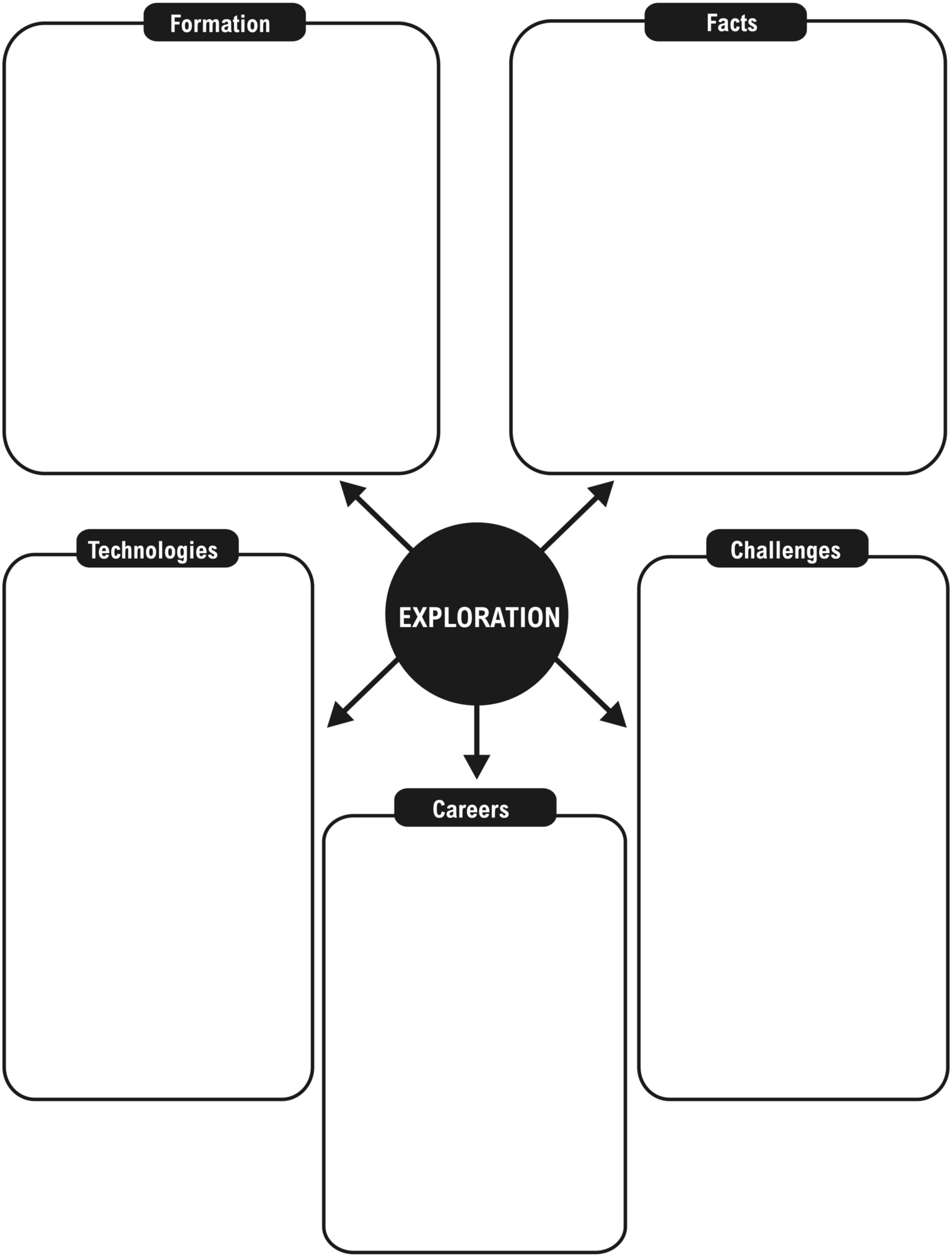
Petroleum Geologist - gather, process, and analyze seismic data and well data in order to locate drill sites for their companies

Geoscientist - study the composition, structure, and other physical asepcts of the earth and are involved in exploration and production of oil and natural gas

Petroleum Engineer - play a key role in determining the reservoir capacity (how much oil it might hold) and productivity (how much it produces) to designing systems that move the petroleum from the wells (production process) through refining, where it gets cleaned up and converted into the energy we use

Chemical Engineer - design chemical plant equipment and develop processes for manufacturing chemicals and products like gasoline, detergents, and plastics

Mechnanical Engineer - deal with the design, manufacture and operation of the machinery and equipment used to improve oil drilling, and the processing of petroleum or chemical products. They also might design and test wind turbines or the devices used to generate hydropower.


Formation
Facts
Technologies
EXPLORATION
Challenges
Careers

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Geology

PRODUCTION

Technologies

Challenges

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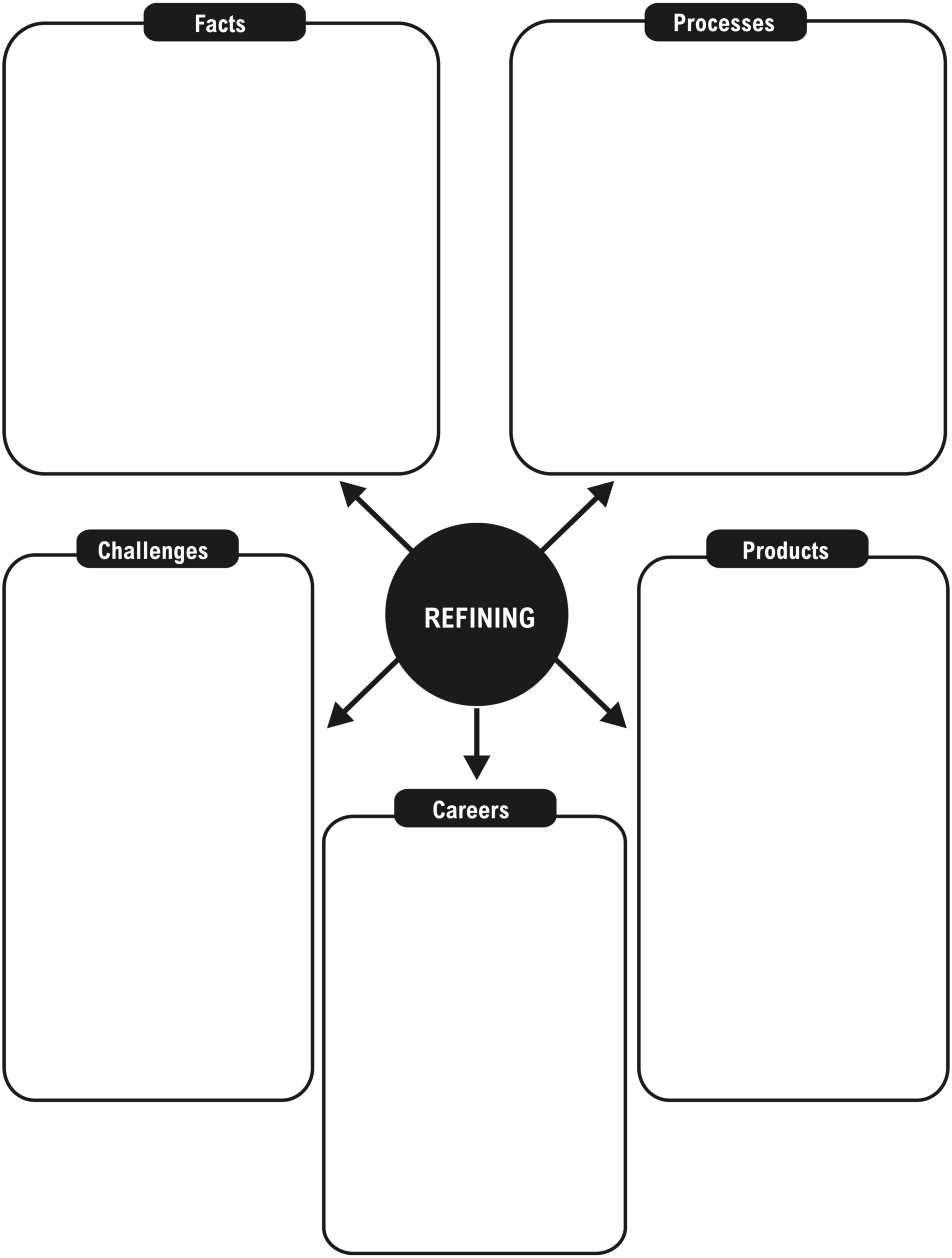
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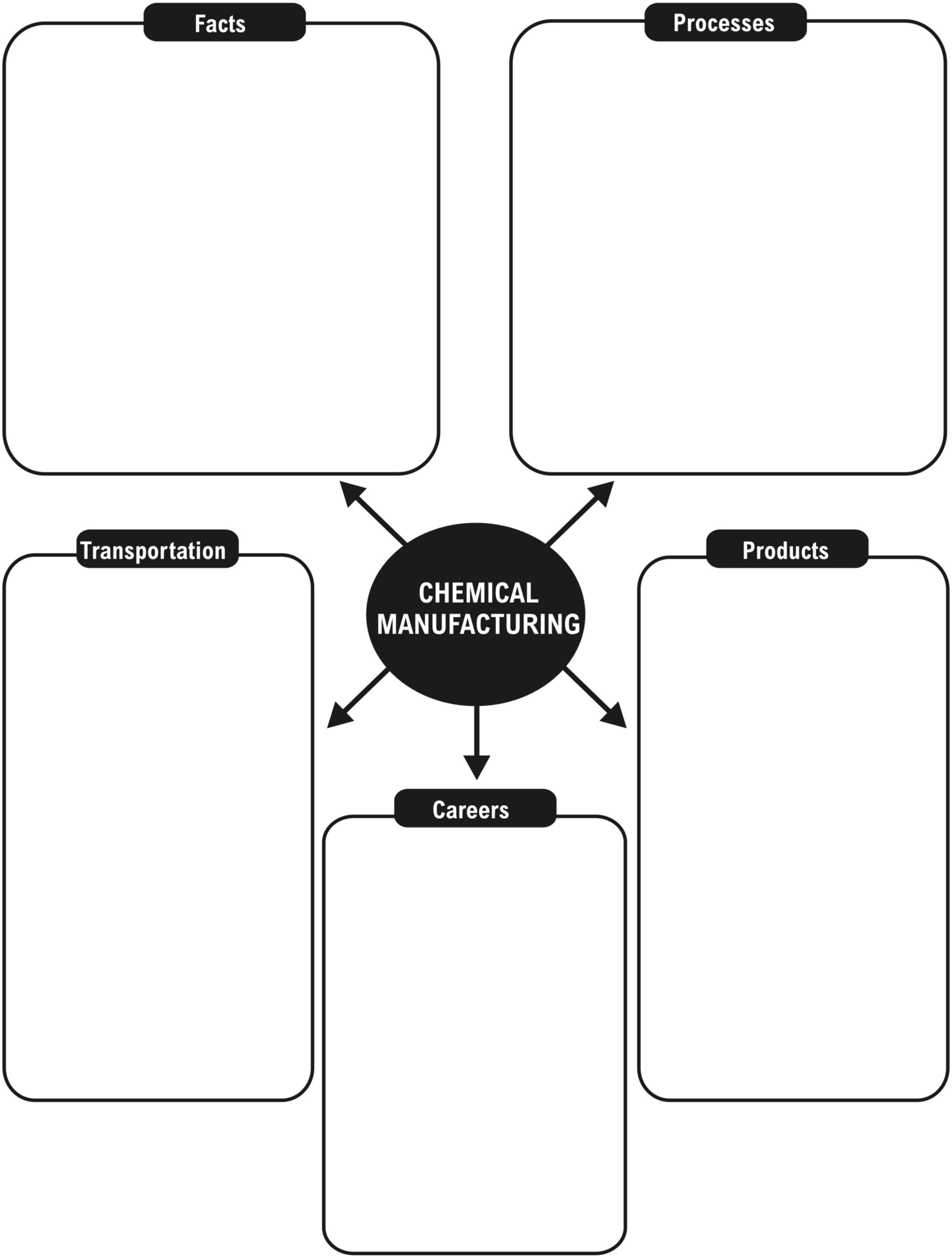
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Transportation
CHEMICAL
MANUFACTURING
Products
Careers

Jigsaw Role Questions and Presentation Questions

Exploration: Geologist

1. Why is an understanding of fossil fuel formation helpful in locating oil reservoirs?
2. What geological characteristics are associated with oil reservoirs?
3. What technologies are used to locate oil reservoirs?
4. What types of careers are available in oil exploration?

Production: ROVER Operator

1. What technologies are used to drill for oil?
2. What physical characteristics of rock formations are important when drilling for oil?
3. How does offshore drilling differ from drilling on land?
4. What types of careers are available in oil production?

Refining: Lab Technician

1. What are the important characteristics of hydrocarbons?
2. What are the processes involved in refining crude oil?
3. What products come from refining crude oil and how are they used?
4. What types of careers are available in oil refining?

Manufacturing: Process Technician

1. What are feedstocks and how are they used?
2. What equipment and processes are involved in chemical manufacturing?
3. What are some of the important products of chemical manufacturing?
4. What types of careers are available in chemical manufacturing?

Transportation: Pipeline Inspector

1. What types of transportation are used in oil production?
2. What are the hazards of transporting petroleum and its products?
3. How are pipelines maintained?
4. What types of careers are available in petroleum transportation?

Consumer

1. What petroleum products do average Americans use every day?
2. Where does the U.S. get its crude oil?
3. What are current economic trends in the oil industry?
4. What are the environmental impacts of petroleum production and consumption?

Presentation Questions:

1. What are the advantages of using petroleum?
2. What are the disadvantages of using petroleum?
3. Does the use of petroleum provide more benefits or risks to society?
4. How would a sharp increase in the price of crude oil affect the standard of living in the U.S.?
5. What can consumers do to ensure that future generations will receive the benefits of petroleum products?

Exploration Activities

Activity 1. Exploring Sound Waves

Materials

- 1 metal slinky spring
- 2 metal cans
- 1 mallet
- 1 packet of clay

Preparation

Line the bottom of one of the metal cans with a layer of clay.

Procedure

1. Have two students hold the ends of the spring at opposite ends of a long table or on a smooth floor.
2. Have one of the students quickly and sharply push forward, then pull back, on the end of the spring to create a longitudinal wave. Explain that longitudinal waves, or vibrations, are the way in which sound or seismic waves travel.
3. Have the students experiment with different amounts of force and speed, and observe the difference in the waves.
4. Tap the mallet on the bottom of each can. Have the students observe the differences in the sound produced with each can.
5. Explain that sound waves travel in different ways in different materials and that seismic technology makes use of this property to locate specific geologic formations underground.

Activity 2. Exploring Core Sampling

Materials

- 4 bags of art sand, each bag should be a different color.
- 10 clear plastic straws
- 1 opaque plastic container
- water

Preparation

Fill the plastic container with several layers of the art sand. After you put a layer down, lightly sprinkle water over the sand. You want it damp, but not soaking. Repeat this after each layer.

Procedure

1. Give a straw to one of the students and have him/her push it straight down through all of the layers in the container, then place a finger tightly over the top of the straw and withdraw it from the container. Have the students observe the layers in the core sample. Allow several students to repeat the process in different places in the container.
2. Explain to the students that core sampling is one way that geologists determine the geologic formation of rocks and sediment when exploring for oil and gas.

Optional

1. Give each student a small Dixie cup and let them layer the sand. After each layer they should sprinkle a small amount of water on top. Have students switch cups with a partner and then pull up a core sample using the

Production Activities

Activity 1. Exploring Density

Element	Density @ 20°C
Hydrogen	0.08 g/cm^3
Carbon	3.51 g/cm^3
Oxygen	1.33 g/cm^3
Sodium	0.97 g/cm^3
Chlorine	2.95 g/cm^3
Calcium	1.54 g/cm^3
Zinc	7.14 g/cm^3
Bromine	3.12 g/cm^3
Gold	19.32 g/cm^3

Materials

- 1—600 ml beaker
- corn syrup, dyed with food coloring
- water
- vegetable oil
- plastic button
- grape
- small cork
- penny
- glass marble
- wooden bead
- ice cube

Procedure

1. Pour 100 ml of corn syrup, vegetable oil, and water into the container.
2. Let the liquids settle for a few minutes.
3. Drop the button, grape, penny, marble, wooden bead, and cork into the container.
4. Observe where the objects settle in the container.

Explanation

The corn syrup, water, and vegetable oil have different densities and will form layers in the containers—the densest will be at the bottom. The objects also have different densities—they will settle in different layers of the mixture. Each object will sink to the layer that has a greater density than it does, then float on that layer.

Extension Activity

Density is defined as mass per unit volume (**D = m/v**). The density of water is the standard at 1.00 g/cm^3. Discuss the densities of the elements in the chart above. Have the students use the formula for density to calculate the following densities:

1000 cm^3 of oil with a mass of 881 g: ________

100 cm^3 of aluminum with a mass of 270 g: ________

10 cm^3 of copper with a mass of 89.3 g: ________

200 cm^3 of nickel with a mass of 1780 g: ________

Activity 2. Exploring Porosity

Materials

- 1 bag small rocks
- 1 bag of small gravel
- 1—100 ml graduated cylinder
- 1 bag medium gravel
- 3—600 ml beakers
- water, dyed with food coloring

Procedure

1. Fill one beaker to the 350 ml mark with large rocks, fill a second beaker with 350 ml of medium gravel, and fill the third with 350 ml of small gravel.
2. Fill the graduated cylinder with 100 ml of water dyed with food coloring.
3. Slowly pour water into the first beaker until the water just reaches the top of the rocks. Record exactly how much water you poured into the beaker. (If you need more than 100 ml of water, fill the graduated cylinder again.)
4. Follow Step 3 again for the other two beakers.
5. Calculate the porosity of the three materials using this formula: $\textbf{Porosity} = \frac{\text{Volume of Water}}{\text{Volume of Material}} \times 100 =$

Porosity of Small Rocks:

Porosity of Small Gravel:

Porosity of Medium Gravel:

Refining Activities

Activity 1: Distillation Products

Materials

- transparency of Fractional Distillation graphic
- Refinery Product cards
- overhead projector
- chalk board

Preparation

1. Make a transparency of the Fractional Distillation Transparency Master.
2. Copy the Refinery Products page on card stock and cut out each product.
3. Draw a thermometer on the board with a range of 0 to 700^{o}C.

Procedure

1. Distribute one Product Card to each student. Instruct each student to write the uses and importance of his/her product on the back of the card. Give the students ten minutes to research information about their products.
2. Display the Fractional Distillation transparency and instruct each student to find his/her product on the graph and note the boiling point.
3. Point out that the density of the products increases as the number of carbon atoms in the products increases.
4. Explain that the activity involves heating crude oil as shown on the thermometer on the board. Explain that you will increase the temperature of the crude oil by 10 degrees Celsius at a time. Ask the students to hold up their hands as their products are being separated out from the crude oil.
5. When the students raise their hands, ask each in turn to stand up and tell the class the uses and important facts about his/her product.

Activity 2. The Refining Process

Materials

- 1/4 cup salt
- 2 cups water
- cup or mug
- small pan with lid that is too large (flat lids are best)
- heating element

Procedure

1. Stir salt and water together in sauce pan.
2. Boil with lid hanging over the edge.
3. Place cup under the lid to catch the distilled water droplets.
4. Allow boiled water to cool.
5. Compare the taste of the water in the pan with the water in the cup.

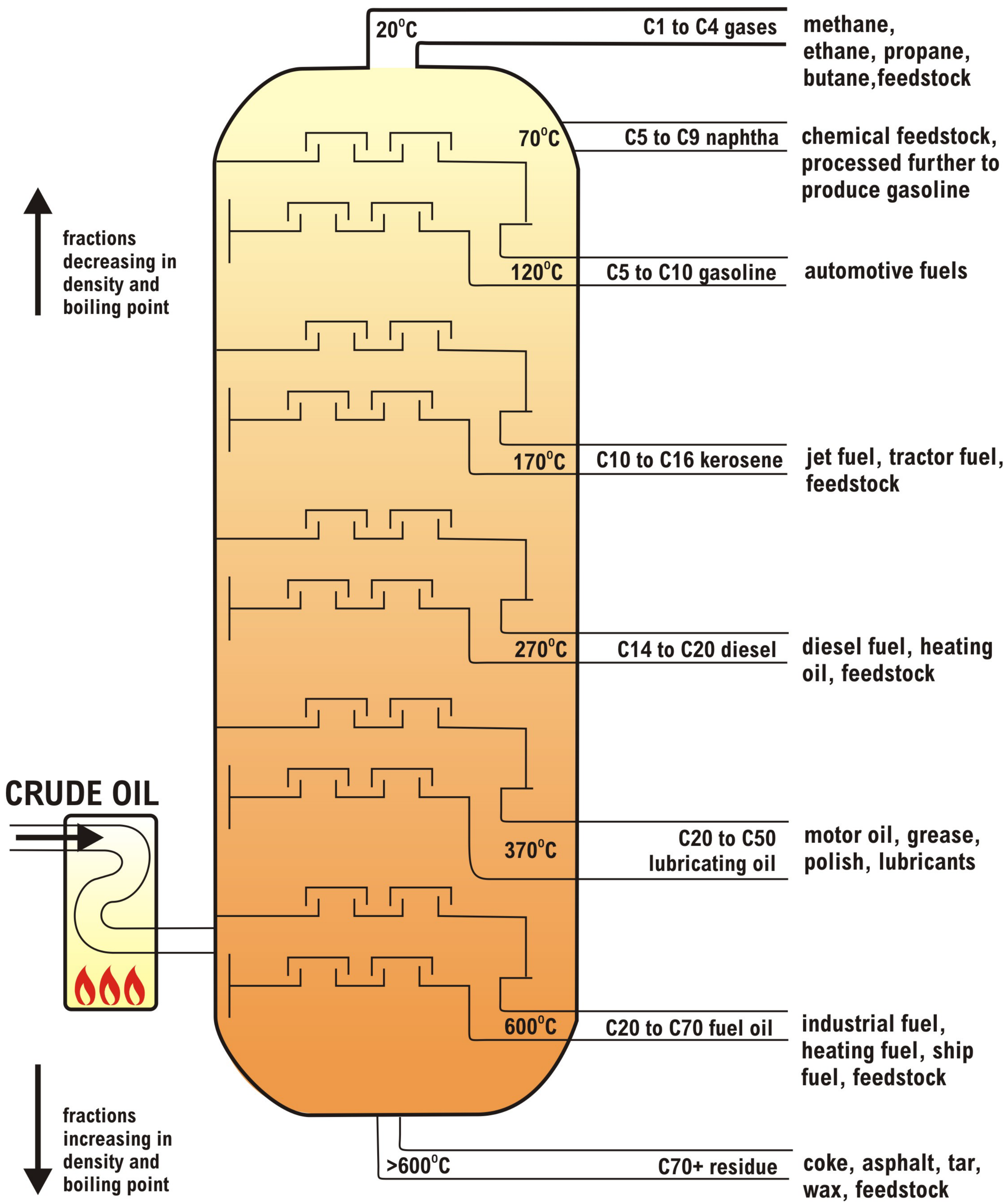
Questions:

1. How does this demonstrate the water cycle: evaporation and condensation?
2. What causes the water to change from a liquid to a gas and back to a liquid?
3. Why is the water in the cup less salty than the water in the pan?

Reflection:

1. How does the oil and gas industry use this science in the refining process?

Fractional Distillation



Refinery Product Cards

propane	jet fuel	industrial fuel oil
methane	tractor fuel	heating fuel oil
ethane	kerosene	feedstock from fuel oil
butane	feedstock from kerosene	coke
petroleum gas feedstock	diesel fuel	asphalt
chemical feedstock	heating oil	tar
gasoline from processed naphtha	feedstock from diesel	wax
high octane gasoline	motor oil	feedstock from residue
mid octane gasoline	grease	fuel for ships
regular octane gasoline	lubricants	shoe polish

Chemical Manufacturing Activities

Activity 1. Slush Powder

Definitions

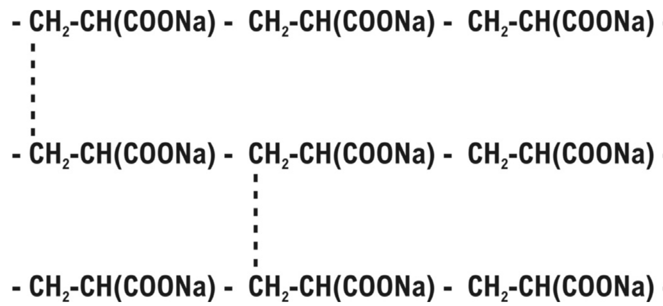
Polymer—a large organic molecule formed by combining many smaller molecules (monomers) in a regular pattern.

Monomer—a molecule that can combine with other molecules to form a polymer.

Dissociate—to split into simpler groups of atoms, single atoms, or ions.

Background

The chemical name for slush powder is sodium polyacrylate. It is a polymer containing many repeating molecules called acrylate monomers connected end-to-end in a large chain. Sodium acrylate is a chain made of carbon, oxygen, hydrogen and sodium. Cross-links between the sodium acrylate chains (- - - - - -) tether the chains together into sodium polyacrylate. These repeating molecules can be thousands to millions of units long.



Sodium polyacrylate, nicknamed the super slurper, is called a superabsorber because it has the ability to absorb large quantities of water. It can absorb 400-800 times its mass in water, but does not dissolve into a solution because of its three-dimensional network structure. Its liquid-like properties result from the fact that the polymer is composed almost entirely of water. Its solid-like properties are due to the network formed by the cross-links.

Sodium polyacrylate is called a hydrophilic or "water-loving" polymer because of its great affinity for water. So how does this polymer work? In its dry powdered state, the chains of the polymer are coiled and lined with carboxyl groups (–COOH). When water is added, the carboxyl groups dissociate into negatively charged carboxylate ions (COO^{-1}). These ions repel one another along the polymer chain, widening the polymer coils and allowing water to move into contact with more carboxyl groups. As the polymer continues to uncoil, it becomes a gel.

Sodium polyacrylate is used as an absorbent material in disposable diapers and to retain water around plants. It is considered non-toxic, but inhalation of airborne particles of the powder or contact with the eye can cause serious adverse reactions. It is for this reason that using a disposable diaper to obtain the powder is discouraged.

To dispose of the gel, add salt. The presence of salt in the solution greatly decreases the ability of the polyacrylate to absorb and retain water. Once the gel has liquefied, it can be safely poured down a drain.

Materials

- sodium polyacrylate
- 1—600 ml beaker
- 1—25 ml graduated cylinder
- water
- salt

Procedure

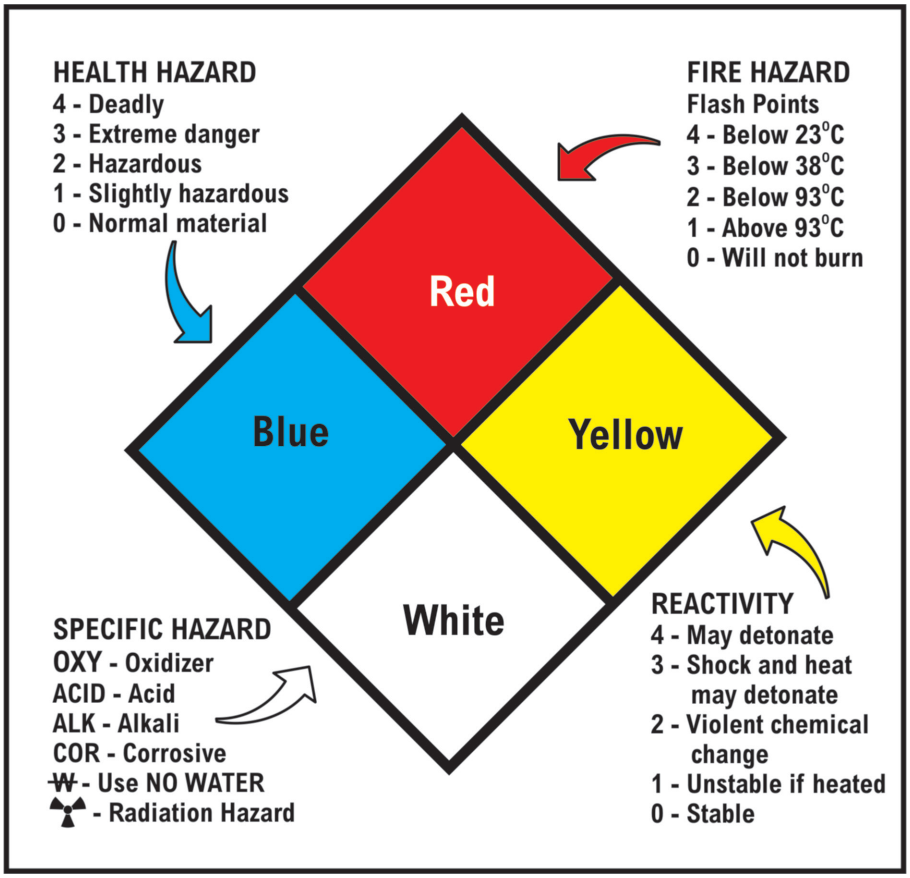
1. Place 1 cc (ml) of sodium polyacrylate in the beaker.
2. Add 10 ml of water to the beaker, then turn the beaker upside down. Observe.
3. Continue adding water until the sodium polyacrylate absorbs no more water.
4. Determine the percentage of water that was absorbed.

Extensions

1. Experiment with varying strengths of salt water solution to determine how much a given amount of sodium polyacrylate can absorb.
2. Experiment with different brands of diapers to see which is the most absorbent. Use a 1 percent salt water solution for this experiment, since urine is approximately 1 percent saline.

Activity 2. Safety First: Chemical Hazard Placards

Chemical hazard placards are placed on laboratories and rooms in which specific chemicals are used and stored to let safety personnel know of the dangers. The placards have four squares—three colored squares and one open square that represent different types of hazards. The levels of the hazards are written in the squares, as defined in the placard below.



1. Defining Terms

Examine the placard explanation above. Define the following words:

Oxidizer:

Acid:

Alkali:

Corrosive:

Detonate:

Unstable:

2. Temperature Conversions

Convert the flash points on the Fire Hazards from Celsius to Fahrenheit using the formula: $F = \frac{9}{5} C + 32$

$23^oC =$

$38^oC =$

$93^oC =$

3. Identifying Chemical Hazard Placards

Below are six chemical hazard placards and six descriptions of different chemicals. Read the chemical descriptions and match each chemical to its chemical hazard placard.

_____ **Calcium** is a silvery, moderately hard metallic element that constitutes about three percent of the earth's crust and is a basic component of most animals and plants. It occurs naturally in limestone, gypsum, and fluorite, and its compounds are used to make plaster, quicklime, Portland cement, and metallurgic and electronic materials. It can be slightly hazardous to human health, and is slightly flammable. It can produce a violent reaction when it comes into contact with water.

Physical State: solid Boiling Point: 1,487°C Appearance: silver-white Odor: odorless

_____ **Methane** is an odorless, colorless, flammable gas, CH_4, the major constituent of natural gas. It is used as a fuel and is an important source of hydrogen and a wide variety of organic compounds. It is hazardous to human health and is an extreme fire hazard. It is a stable gas.

Physical State: gas Flash Point: -188°C Appearance: colorless Odor: odorless

_____ **Benzene** is a colorless, very flammable, toxic liquid aromatic hydrocarbon, C_6H_6, derived from petroleum and used in or to manufacture a wide variety of chemical products, including solvents, detergents, insecticides, and motor fuels. It can be hazardous to human health. It is a stable compound.

Physical State: liquid Boiling Point: 80°C Appearance: colorless Odor: gasoline-like

_____ **Butane** is either of two isomers of a gaseous hydrocarbon, C_4H_{10}, produced from petroleum and used as a household fuel, refrigerant, aerosol propellant and in the manufacture of synthetic rubber. It can be slightly hazardous to human health and is an extreme fire hazard. It is a stable compound.

Physical State: gas Flash Point: -76°C Appearance: colorless Odor: faint, disagreeable

_____ **Sulfuric Acid** is a highly corrosive, dense, colorless, oily liquid, H_2SO_4, used to manufacture a wide variety of chemicals and materials including fertilizers, paints, detergents, and explosives. It can pose an extreme danger to human health and is unstable, capable of causing violent chemical change. Reacts violently with water.

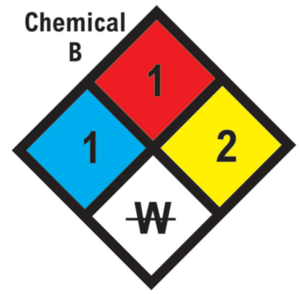
Physical State: liquid Boiling Point: 290°C Appearance: colorless Odor: sulfurous

_____ **Phosphorus** is a highly reactive, deadly poisonous, nonmetallic element occurring naturally in phosphates. It is used in safety matches, pyrotechnics, and fertilizers and to protect metal surfaces from corrosion. It is extremely flammable and is unstable, capable of violent chemical change.

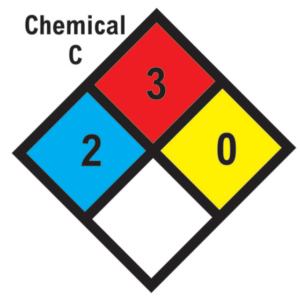
Physical State: solid Boiling Point: 280°C Appearance: white-to-yellow Odor: odorless

Chemical A

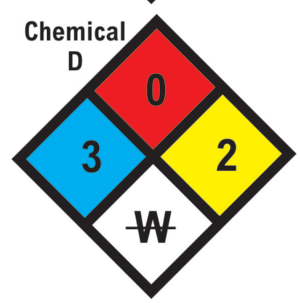
Chemical B



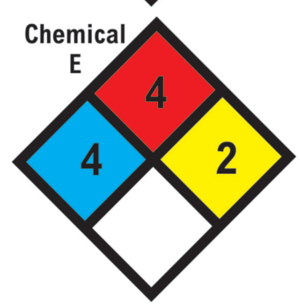
Chemical C



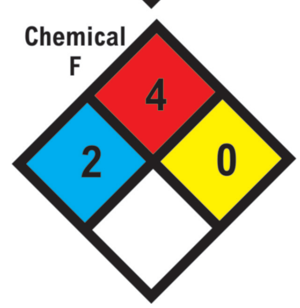
Chemical D



Chemical E



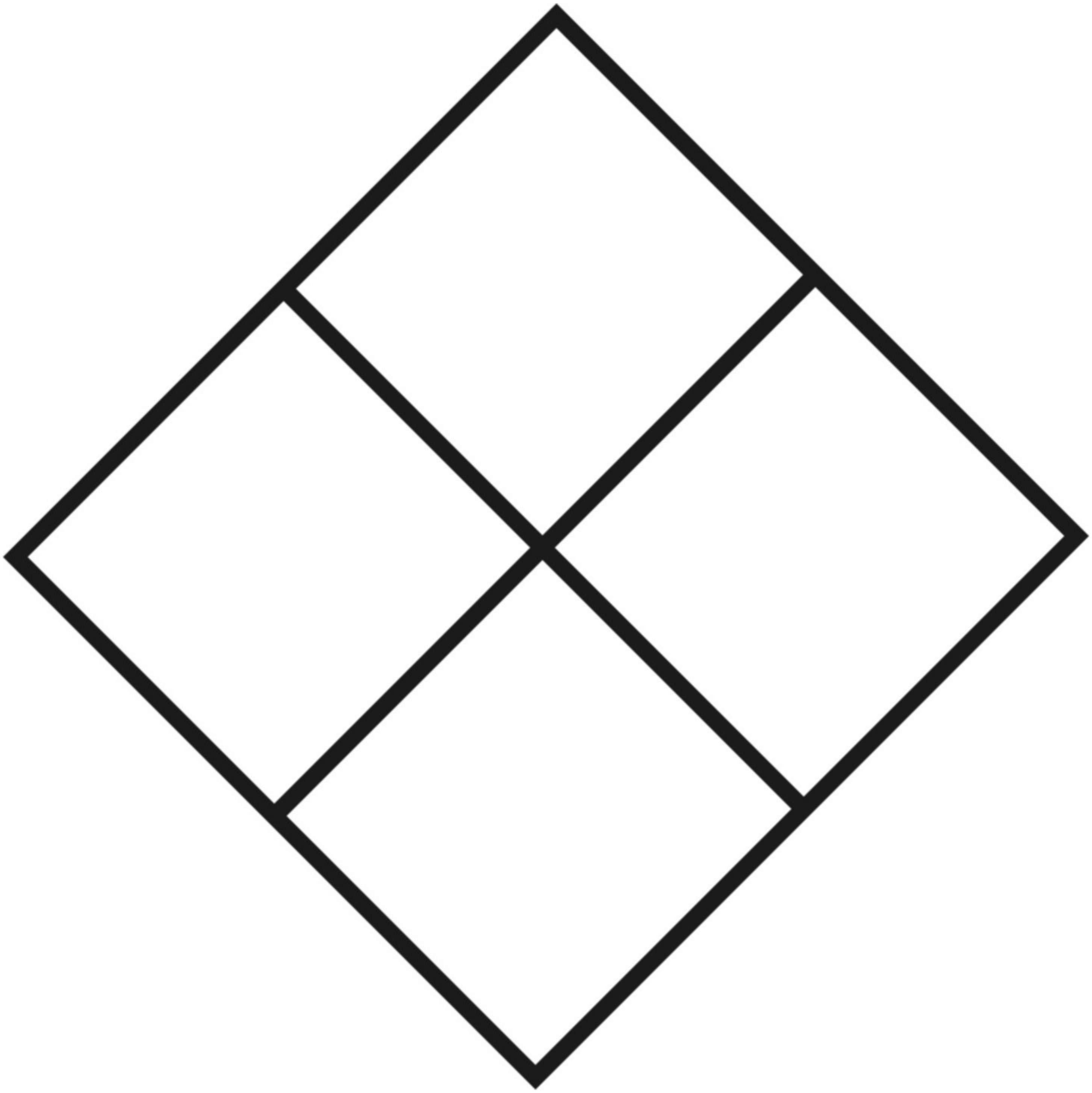
Chemical F



4. Make a Chemical Hazard Placard

Make your own chemical hazard placard. Choose a chemical you've heard about and research its characteristics and uses, then draw a placard for the chemical using the blank placard on the next page. Display your placard and tell your classmates about the characteristics and uses of your chemical.

Uses:



Chemical:

Chemical Formula:

Characteristics:

Uses:

Oil Industry in the Round Activity

I have **Alteration**. **THE END** **START:** Who has a name for fuels formed from the remains of ancient sea plants and animals?	I have **Metamorphic.** Who has the study of rock layers to determine the origin and composition of rocks?	I have **Drilling Mud.** Who has the term used to describe the gaps or pores where oil is stored?
I have **Fossil Fuel**. Who has the term for energy sources that take millions of years to form?	I have **Stratigraphy.** Who has the measure of a rock's ability to hold and move fluids?	I have **Porosity.** Who has the process used to turn an exploratory well into a production well?
I have **Nonrenewable.** Who has the name of the main component of natural gas?	I have **Permeability.** Who has the technology that uses sound waves to explore underground rock formations?	I have **Completion.** Who has the term used to indicate the amount of water in an oil deposit?
I have **Methane.** Who has the type of rock made from layers of sand and sediment?	I have **Seismic.** Who has a device used to create underground shock waves?	I have **Saturation.** Who has the term that describes nearby oil reserves that are not connected to each other?
I have **Sedimentary.** Who has the energy source used the most in the U.S.?	I have **Thumper.** Who has an advanced visualization technology to understand seismic data?	I have **Compartmentalization.** Who has the device used to regulate high pressure in a production well?
I have **Petroleum (oil).** Who has the area that produces a third of all crude oil in the U.S.?	I have **CAVE.** Who has a a new type of seismic technology that measures changes over time?	I have **Blow Out Preventor (BOP).** Who has the term used when a well has enough pressure to lift the oil?
I have **Offshore.** Who has the sector of the economy that uses two-thirds of U.S. oil?	I have **4D Seismic.** Who has the structure used to test for underground oil with an exploratory well?	I have **Natural Drive.** Who has the process of separating crude oil into its major components using boiling range?
I have **Transportation.** Who has the type of rock that is formed from magma?	I have **Drilling Rig.** Who has the term for petroleum products that are used to make other products in chemical plants?	I have **Distillation.** Who has the process of using heat to break long hydrocarbon chains into smaller chains?
I have **Igneous.** Who has the type of gases that keep the earth warm enough for human life?	I have **Feedstocks.** Who has the term for the rock that is disturbed by the drilling process?	I have **Thermal Cracking.** Who has the process of combining short hydrocarbon chains into longer chains?
I have **Greenhouse.** Who has the type of rock made from extensive heat and pressure on other rocks?	I have **Debris.** Who has the term for the material used to lift debris from a well?	I have **Unification.** Who has the process of rearranging the molecules in hydrocarbon chains?

Synthesis Activity

Fossil Fuels to Products

Students will create a flow chart mural of petroleum from formation to disposal, with each student representing a different product.

Materials

- large piece of mural paper
- colored markers

Procedure

1. Assign a product role to each student, using the list below and any others you wish:

   asphalt, aspirin, butane, carpeting, CD, coke, naphtha, contact lenses, cosmetics, crayon, credit card, diaper, diesel fuel, electricity, fertilizer, glue, grease, hand lotion, heating oil, industrial fuel, jet fuel, laundry detergent, ethane, lubricants, methane, milk jug, gasoline, motor oil, paint, pen ink, trash bag, plastic container, propane, prosthetic heart valve, soda bottle, tar, tire, toothbrush, toothpaste, tractor fuel, wax, shoe polish.
2. Have each student prepare a flow chart of his/her product's lineage from formation to final product to use or disposal.
3. Explain to the students that after they create their personal flow charts, they will create a classroom flow chart that includes the lineage of every product in the class. Have the students brainstorm ideas for creating a combined flow chart. They will need to find out what the products have in common within each lineage and may find it helpful to group themselves by boiling point or some other characteristic. Once students have discovered and agreed upon patterns in their flow charts, sketch out a master flow chart on large chart paper at the front of the room.
4. All products started out as ancient sea plants and animals, so formation can go at the beginning of the flow chart. Offshore and onshore exploration and production can divide into two areas, and then the flow chart can come back together after transportation to the refining phase. After refining, have the students begin to add their individual products to the flow chart. Some products will move straight to transportation and market, others to chemical processing, then to market. Have students add product uses to the flow chart.
5. Have the students add colored lines to the flow chart detailing the way their products are transported from origin to market; pipeline = red, truck = blue, ship = green, for example.
6. Brainstorm disposal methods for some products that are not consumed, such as plastic objects. See NEED's **Museum of Solid Waste and Energy** for information on preferred disposal methods for plastics and other waste products.
7. Have students answer the following discussion questions in their science journals.

Discussion Questions

1. What do CDs and diesel fuel have in common?
2. What do you think is the most important product created from crude oil? Why do you think so?

Extension Activity

Discuss question two as a group. List each student's opinion of the most important product derived from crude oil. Debate the choices. For example, which is more important: diesel fuel to ship goods, gasoline for personal transportation, medicines, or plastics for heart valves?

Fossil Fuels to Products Pre/Post Survey

1. **Petroleum and natural gas are:**
   a. fossil fuels b. nonrenewables c. hydrocarbons d. all three

2. **Which energy source meets more energy demand than any other in the United States?**
   a. natural gas b. petroleum c. solar d. coal

3. **Petroleum and natural gas are usually found in which type(s) of rock formations?**
   a. sedimentary b. metamorphic c. igneous d. all three

4. **Which sector of the economy uses the highest percentage of petroleum products?**
   a. industrial b. residential c. commercial d. transportation

5. **Geologists using advanced technologies to explore for oil are successful what percentage of the time?**
   a. 10-20 percent b. 40-50 percent c. 70-80 percent d. 90-100 percent

6. **What percentage of oil does the U.S. import from other countries?**
   a. 20-30 percent b. 40-50 percent c. 60-70 percent d. 80-90 percent

7. **What percentage of oil does the industrial sector in the U.S. use for energy and to manufacture products?**
   a. 5 percent b. 10 percent c. 15 percent d. 25 percent

8. **How much U.S. oil production comes from offshore wells?**
   a. 10 percent b. 33 percent c. 50 percent d. 75 percent

9. **Crude oil must be processed before it can be used.**
   a. true b. false

10. **Most crude oil is processed into diesel fuel for trucks, boats, trains, and other heavy vehicles.**
    a. true b. false

11. **Crude oil must be processed at a refinery before it is usable by consumers.**
    a. true b. false

12. **Refineries separate petroleum products according to their boiling point by distillation.**
    a. true b. false

13. **Crude oil contains only liquid products.**
    a. true b. false

14. **Most petroleum products are transported by large oil tankers.**
    a. true b. false

15. **Chemical plants make thousands of different chemicals, plastics, medicines, cosmetics, clothing, tires, and other products we use every day from petroleum products.**
    a. true b. false

16. **The price of oil affects all sectors of the U.S. economy.**
    a. true b. false

Glossary

acid—any of various water-soluble compounds having a sour taste and capable of turning litmus red and reacting with a base to form a salt

alkali—any substance having basic (as opposed to acidic) properties

alkylation—mixing a hydrocarbon with a catalyst and an acid to create different hydrocarbons

alteration—a process that rearranges pieces of hydrocarbon chains into different hydrocarbons

aromatic—cyclic hydrocarbon in the shape of a ring rather than a chain

blow out preventor (BOP)—a device that controls the pressure of a well

boiler—equipment used to process petroleum products with heat

casing—process of lining a production well with pipe before production can begin

catalytic cracking—using a catalyst to break long hydrocarbon chains

catalytic reformatting—using a catalyst to rearrange hydrocarbon chains

CAVE—sophisticated technology for visualizing data from seismic systems

cementing—stabilizing a casing pipe in a production well with cement

christmas tree—a series of valves and gauges that controls the flow of a well with natural drive

coke—a carbon-rich substance used by heavy industry

coking—heating the residue from the distillation process to produce useful products such as coke

compartmentalization—a situation in which oil from one part of a reserve cannot flow to another part of the reserve because of characteristics of the rock formation

completion—preparing an exploratory well for production

condense—to change state from gas to liquid

cooling tower—equipment used to cool water that has been heated during chemical processing

corrosive—having the capability or tendency to cause corrosion or gradual destruction

cracking—a process that breaks long hydrocarbon chains into shorter chains

data log—comprehensive information about a well's production data over time

debris—the rock that is torn up by a drill bit and must be removed from a well

density—a measure of the amount of mass contained in a given volume

detonate—to set off an explosion

distillation—separation of substances based on their boiling range

drilling rig—the equipment used to drill a well

drilling mud—the substance used to lift debris from a well during drilling

exploratory well—a well dug to find out if oil or natural gas is present in a location

field processing—processing of crude oil at an offshore production site to separate the crude oil, natural gas, and salt water

fossil fuel—energy-rich hydrocarbon made from the ancient remains of organic matter

fractioning tower—equipment in which distillation takes place

greenhouse gas—any gas in the atmosphere that contributes to the greenhouse effect

heat exchanger—a device that uses waste heat from one chemical process in another process

heat-treater—a device used to remove water from crude oil

horse head pump—a pump with a crank arm that lifts oil to the surface of a production well

hydrocarbon—a chemical compound containing only hydrogen and carbon

igneous rock—rock formed from magma or liquid rock that exists inside the earth

loading station—an area where products are stored until shipped to market

mercaptan—an odorant added to natural gas as a safety feature

metamorphic rock—rock with few pores made from sedimentary or igneous rock under intense pressure

methane—the main ingredient in natural gas

monomer—a molecule that can combine with other molecules to form a polymer

mud—the substance used to lift debris from a well during drilling

natural drive—pressure in a production well with enough force to lift the crude oil to the surface

nonrenewable energy source—an energy source that takes millions of years to form

olefin—a hydrocarbon that contains one or more pairs of carbon atoms linked by a double bond

organic compound—a compound containing hydrogen and carbon made of once living material

oxidizer—a substance that gives up oxygen easily to stimulate combustion of organic material

perforating—making holes in the bottom portion of a casing pipe so that oil can flow into it

permeability—a measure of the ability of a rock to hold and move fluids

pig—a device used to clean a pipeline

polymer—a large organic molecule formed by combining many smaller molecules (monomers) in a regular pattern

porosity—relating to the pores or gaps between the grains of rock in which oil is stored

pressurized separator—a device that uses pressure to quickly separate crude oil, natural gas, and salt water during field processing

processing platform—an offshore platform where oil is cleaned and combined with oil from other wells before it is sent to a refinery

pumping station—a device along a pipeline with pumping equipment to keep the product flowing through the pipeline

renewable energy source—an energy source that can be replenished in a short period of time

roustabout—a worker on a drilling rig

ROVER—a Remote Operating Vehicle used to maintain and repair undersea drilling equipment

saturation—the amount of water contained in crude oil

sedimentary rock—rock formed from layers of sand and sediment under pressure

seismic technology—equipment that bounces sound waves off of underground rock to determine the characteristics of rock formations

settling tank—a tank used to separate crude oil, natural gas, and salt water on a processing platform

smart pig—a device that uses a camera to monitor a pipeline for flaws

stratigraphy—the study of rock layers to determine data about the rock formation, the age of the layers, the radioactivity, and other information

sucker-rod pump—a pump that draws crude oil to the surface of a production well

tank farm—a group of oil storage tanks

thermal cracking—a process that uses very high temperatures to break apart long hydrocarbon chains

thumper—a device that produces sound waves in seismic technology

treatment—process of removing impurities from petroleum products before they are shipped to market

unification—a process that combines smaller hydrocarbon chains into longer chains

unstable—having a tendency to react easily with other substances

wastewater treatment—processes that ensure that the water leaving a chemical plant is as clean as when it entered the plant

FOSSIL FUELS TO PRODUCTS

Evaluation Form

State: ___________ **Grade Level:** ___________ **Number of Students:** __________

1. Did you conduct the entire unit?	Yes	No
2. Were the instructions clear and easy to follow?	Yes	No
3. Did the activities meet your academic objectives?	Yes	No
4. Were the activities age appropriate?	Yes	No
5. Were the allotted times sufficient to conduct the unit?	Yes	No
6. Was the unit easy to use?	Yes	No
7. Was the preparation required acceptable for the activities?	Yes	No
8. Were the students interested and motivated?	Yes	No
9. Was the energy knowledge content age appropriate?	Yes	No
10. Would you use the unit again?	Yes	No

How would you rate the unit overall (excellent, good, fair, poor)?

How would your students rate the unit overall (excellent, good, fair, poor)?

What would make the unit more useful to you?

Other Comments:

Please fax or mail to:

NEED Project
PO Box 10101
Manassas, VA 20108
FAX: 1-800-847-1820

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National Ocean Industries Association
National Renewable Energy Laboratory
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New Mexico Landman's Association
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Puget Sound Energy
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